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CIVIL ENGINEERING.

On the Construction of Iron Roofs. By Mr. J. J. Birckel.

From the London Artizan, August, 1862.

The rapid introduction of iron in place of wood in the construction of roofs will, we believe, cause our readers to consider the study of the construction of iron roofs as being worthy of their careful attention, and the interest with which they will peruse the subject will, no doubt, be greatly enhanced when we shall point out its bearings upon the security of human life and property.

In order to give our readers a clear insight into this subject, we will first deal with the theoretical questions which it embraces; and, divesting these of all unnecessary scientific difficulties, enable them to learn what should be done in any given case. We shall afterwards lay before them different existing examples of roofs, which will enable them to see what has been done under various circumstances, and which may serve to them as guides in their own future practice.

A roof is, generally, a series of trussed frames, so constructed as that their shape shall not be able to alter; and which, for the convenience of calculation, are supposed to be under the influence of vertical parallel pressures, some of which are permanent, and some casual. The permanent pressures are the weight of the structure of the roof, including frames and covering, and the casual pressures are those of wind, hail, snow, or rain, against all of which provision should be

made. For the sequel, we shall see what are their respective amounts as generally admitted.

Fig. 1.

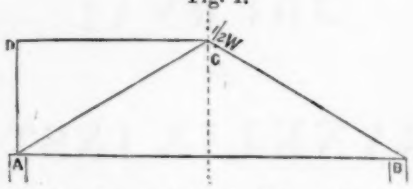


Fig. 1 represents the simplest kind of truss to be met with in roofs of small spans, and consisting of two struts A C, B C, called rafters, and of a tie rod A B: the frame as a whole is called a principal. Let W represent the whole load on one division of the roof, extending between two consecutive principals, the weight on each rafter will be $\frac{1}{2}$ W, and may be supposed to be collected at the points A and C, B and C, so that the weight directly supported at the points A and B is $\frac{1}{4}$ W, and at the point C $\frac{1}{2}$ W; this latter portion is transmitted in equal amounts to the walls or supports, which accordingly sustain each a pressure of $\frac{1}{2}$ W. With the assistance of the theory of parallel projections, so fully illustrated by Professor Rankine, it will now be easy to define the stress on each component part of the principal; for if A D be made to represent $\frac{1}{4}$ W, A C will represent the thrust upon the rafter, and D C the pull upon the tie rod, whence the following:—

In the case of a principal, constructed in the shape of a simple triangular truss, if the rise of the roof be made to represent one-fourth the load on one division of the roof, the thrust on the rafter will be represented by its own length, and the pull on the tie rod by one-half its own length.

This, to be sure, is simple enough; and when we remember that the load on the roof is an assumed one, we may safely say that the results thus obtained are quite as correct as those obtained by means of trigonometric calculations. But, if we must have trigonometric formulæ, we would prefer to have them in a shape which would enable us to solve them by simple reference to a table of sines and tangents; for, as homely practitioners, we are not likely to have at our fingers ends all the transformations which trigonometric formulæ admit of; and, while we have to search in a treatise on trigonometry, we might be usefully employed solving the practical problem upon which we are engaged. The formulæ for the case under the consideration as given by Professor Rankine in his Treatise on Practical Mechanics, are as follows:—Let H be the pull on the rod, R the thrust on the rafter, and i the angle, which the latter makes with the horizon, then—

$$H = \tfrac{1}{4}\frac{W}{\text{tang. } i} \text{ and } R = \tfrac{1}{4} W \text{ cosec. } i.$$

Here we have no difficulty in dealing with the first formula; for we find tang. i or log. tang. i in any trigonometric table; but cosec. i is generally ignored by those tables; and before we can solve the second formula, we must find out what relation cosec. i bears to sin. i, to cos. i,

or to tang. i. On that ground, we would prefer Moseley's formulæ:

$$\text{R} = \tfrac{1}{4} \frac{\text{W}}{\text{sin. } i}$$

which is, indeed, its natural and legitimate form. General Morin, who devotes a considerable space to the subject of construction of roofs in his work on resistance of materials, gives two different values to the pull H on the tie rod. Looking, first, upon the rafter as an isolated beam, subject to the action of an equally distributed load in its length, and at its lower end to the reactions of the wall and of the tie rod, he arrives at the value of H, by imposing upon himself the condition that the deflection of the rafter shall be null, and thus obtains the formula:

$$\text{H} = \tfrac{1}{2} \text{ W } \tfrac{5}{8} \text{ tang. compl. } i = \tfrac{5}{16} \frac{\text{W}}{\text{tang. } i}.$$

In a subsequent article on the same subject, proceeding to determine the value of H, by a method similar to Rankine's method of section, he finds,

$$\text{H} = \tfrac{1}{4} \frac{\text{W}}{\text{tang. } i}$$

which formula is identical with the one quoted in the first instance. Here, then, there is a difference of $\frac{1}{16}$ in the values of H given by Gen. Morin; and as we can detect no errors of calculus, we must look for the origin of that difference; we think, in that previous part of his work in which he deals with the absolute deflection of beams, the formulæ there obtained being here made use of. As the difference is one of excess, however, we have no occasion to quarrel with this author about it, but have pointed it out rather for the purpose of showing that elaborate algebraic calculations may lead to results quite as much at variance with each other as plain geometric manipulations.

Fig. 2.

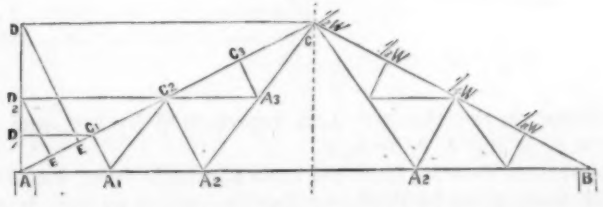


Fig. 2 represents a system of trussing which occurs frequently in iron roofs of large spans. A B C is the primary truss, consisting of the rafters A C, B C, and of the tie rod A B. The rafter is supported in its centre by a secondary truss A C A_2, consisting of the rafter itself, of the two ties A A_2, C A_2, and of the strut C_2 A_2; at the intermediate points C_1, C_3, it is supported also by two minor secondary trusses A C_2 A_1 and C C_2 A_3, similar to the one just described and supported by it. The stresses sustained by the component parts of each individual truss must be determined as if that truss was an independent structure; and to

be able to do that we must see how the load is distributed upon the points A, C_1, C_2, C_3, C, which will be arrived at in the following manner: $\frac{1}{2}$ W being equally distributed upon each rafter, the load directly supported at the points C_1, C_2, C_3, is $\frac{1}{8}$ W, and the load at each point A and B is $\frac{1}{16}$ W; but the minor secondary trusses, through their tension rods, exert a pressure of $\frac{1}{8}$ W, at the point C_2, and of $\frac{1}{16}$ W at each of the points A and B; the major secondary truss exerts a pressure of $\frac{1}{8}$ W at each of the points A and B also, so that the final distribution of the load is, at C $\frac{1}{2}$ W, at each of the points A, B and C_2 $\frac{1}{4}$ W, and at the points C_3 $\frac{1}{8}$ W.

Let A D again represent $\frac{1}{4}$ W, then D C = H will represent the stress on the horizontal rod, arising from the primary truss; D_2 C_2 = H_2 the stress on the ties of the major secondary truss, and D_1 C_1 = H_1, the stress on the tie rods of the minor secondary trusses. The thrust on the rafter arising from the primary truss is represented by its own length A C = R; that on the lower half of the rafter due to the major secondary truss is represented by A C_2 = R_1, and on the upper half by H C_2 = R_2, the difference here arising from the component along the rafter of the weight applied at the points C_2; the stress on the lower half of each portion of the rafter forming part of the minor secondary trusses and arising from the same is A C_2 R_3, and that on the upper halves C_1 E_1 = R_4. The resultant stresses on the various parts of the frames, therefore, will be:—

Pull on the Horizontal Tie Rod.

Between A A_1 = H + H_2 + H_1
" A_1 + A_2 = H_1 + H_2
" A_2 A_2 = H

Rankine's Formulæ.

$$\frac{W}{\text{tang. } i}\left(\tfrac{1}{4} + \tfrac{1}{8} + 1\text{-}16\right)$$

$$\frac{W}{\text{tang. } i}\left(\tfrac{1}{4} + \tfrac{1}{8}\right)$$

$$\frac{W}{\text{tang. } i}\left(\tfrac{1}{4}\right)$$

Thrust on the Rafters.

Between A C_1 = R + R_1 + R_3
" C_1 C_2 = R + R_1 + R_4
" C_2 C_3 = R + R_2 + R_3
" C_2 C = R + R_2 + R_4

Rankine's Formulæ.

W cosec. i $(\frac{1}{4} + \frac{1}{8} + 1\text{-}16)$
W cosec. i $(\frac{1}{4} + \frac{1}{8} + 1\text{-}16 - \frac{1}{8} \sin^2 i)$
W cosec. i $(\frac{1}{4} + \frac{1}{8} + 1\text{-}16 - \frac{1}{4} \sin^2 i)$
W cosec. i $[\frac{1}{4} + \frac{1}{8} + 1\text{-}16 - \sin^2 i\ (\frac{1}{4} - \frac{1}{8})]$

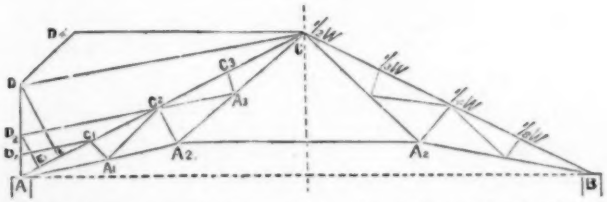
The thrust on the struts C_2 A_2 is represented by D E, and that on the struts C_1 A_1 and C_3 A_3 by D_2 E_1.

These various results, rendered in an algebraic form, would be identical with those given by Professor Rankine, which we have transcribed for inspection by the curious; but as these formulæ are rather complicated, and necessitate the use of the trigonometric tables, the diagram of forces which we have here given will be found far more useful in practice.

As the rafters are generally of uniform strength throughout their length, it will be sufficient to define the maximum thrust upon them, and it will be sufficient also to define the minimum and the maximum pull on the tie rod, and the maximum pull on the braces. A careful investigation of the diagram will show that in the case of a principal,

trussed in the manner illustrated by fig. 2, if the rise of the roof be made to represent one-fourth the load on one principal, the maximum thrust on the rafter is represented by $\frac{7}{4}$ its own length; the minimum pull on the tie rod by $\frac{1}{2}$; and the maximum pull by $\frac{7}{8}$ its own length; the maximum pull on the braces is represented by $\frac{3}{8}$ the length of tie rod. Should the minor secondary trusses be left out, the maximum thrust on the rafter will be represented by $\frac{6}{4}$ its own length; the maximum pull on the tie rod by $\frac{3}{4}$ its own length; and the maximum pull on the braces by $\frac{1}{4}$ the length of the tie rod.

Fig. 3.



Very often, however, the tie rod is raised above the horizontal, and then the diagram of forces assumes a somewhat altered shape. Fig. 3 is an illustration of this case, and the distribution of the load being as previously, if from the point C we draw C D parallel to A A_2, D A will stand for $\frac{1}{4}$ W; C D will represent the pull on the tie A A_2; C D_4, which is horizontal, will represent the pull on the tie A_2 A_2; D D_4, parallel to the brace C A_2, will represent the pull on the same, and A C the thrust on the rafter; all these being due to the primary truss only. The stresses arising from the secondary trusses will be determined as previously, by drawing C_2 D_2 and C_1 D_1 parallel to A A_2, and D H, D_2 H_1, perpendicular to the rafter; finally, the resultant stresses are to be computed as before, care being taken not to omit the additional stress D D_4 on the braces.

Fig. 4.

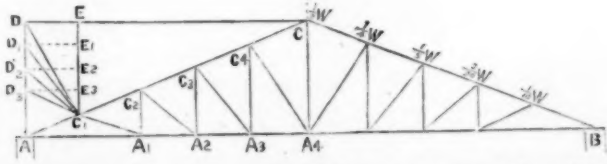


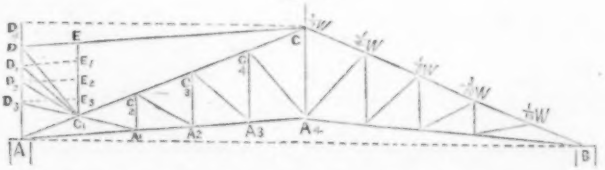
Fig. 4 represents a system of trussing very generally adopted, and roofs so constructed are known by the name of king and queen post roofs. The number of secondary trusses to support the rafter varies according to the span; and, in the present case, it is supported by four of these, which are A A_1 C_1 A A_2 C_2, A A_3 C_3, A A_4 C_4, and the stresses again must be determined for each separately. Here the distribution of the load is as follows:—$\frac{1}{5}$ of the weight on the rafter, or $\frac{1}{10}$ W rests directly on each of the points C_1, C_2, C_3, C_4, and $\frac{1}{20}$ W at A and at C; but by means of the vertical ties connecting the trusses one-half the weight at C_1 is transmitted to C_2; $\frac{2}{3}$ of the load at C_2 is transmitted to

C_3; $\frac{3}{4}$ of the load at C_3 to C_4 and $\frac{4}{5}$ of that at C_4 to C; so that, finally, we have;—At C $\frac{1}{10}$ W; at C_2 $\frac{3}{10}$ W; at C_3 $\frac{1}{5}$ W; at C_4 $\frac{1}{4}$ W; and at C $\frac{1}{2}$ W. If the rise of the roof be made to represent $\frac{1}{4}$ W, D C = H will represent the pull on the tie rod, and A C = R the thrust on the rafter, as due to the primary truss. To determine the stress upon the component parts of each secondary truss from the point C_1, let us draw the line C_1 D parallel to the strut C_4 A_4, C_1 D_1 parallel to C_3 A_3, C_1 D_2 parallel to C_2 A_2, and C_1 D_3 parallel to C_1 A_1. These lines will respectively represent the thrust upon the struts to which they are parallel: D E = H_1 represents the pull on the tie rod, and A C_1 = R_1 the thrust upon the rafter, as due to each secondary truss. It is worth noticing here, that, in this system of trussing, the two latter stresses remain constant for each secondary truss. C_1 E_3, C_1 E_2, C_1 E_1, respectively, represent the pull on the vertical ties A_1 C_2, A_2 C_3, A_3 C_4; and C_1 E represents one-half the pull on the king post A_4 C, the pull here being double that shown by the diagram of forces, because the resultant stress from the corresponding truss on the other rafter is also thrown upon this rod. The resultant stresses, therefore, are as follvws:—

Pull on the Tie Rod.	*Thrust on the Rafter.*
Between A_3 A_4 = $s + s_1$	Between C C_4 = T
" A_2 A_3 = $s + 2\,s_1$	" C_3 C_4 = $T + T_1$
" A_1 A_2 = $s + 3\,s_1$	" C_2 C_3 = $T + 2\,T_1$
" A A_1 = $s + 4\,s$	" C_1 C_2 = $T + 3\,T_1$
	" A C_1 = $T + 4\,T_1$

And the maximum stresses are, for the pull on the tie rod, represented by $\frac{9}{10}$ its own length, and for the thrust on the rafter by $\frac{9}{5}$ its own length; but if the number of secondary trusses on each rafter were reduced to three, the maximum stresses would be as in the trussing illustrated by fig. 2; viz. the thrust on the rafter represented by $\frac{7}{4}$ its own length, and the pull on the tie rod by $\frac{7}{8}$ its own length.

Fig. 5.



In this system of trussing, also, the tie rod is generally raised out of the horizontal line, as shown by fig. 5, and the diagram of forces, which, it may be well to state, hold good for any number of secondary trusses, undergoes a slight modification. In this case C D is to be drawn parallel to A A_4, and A D = C A_4 is to stand for $\frac{1}{4}$ W; C D then will represent the pull on the tie rod, A C the thrust on the rafter, and 2 D D_4 the pull on the king post, as arising from the primary truss. The stresses due to the secondary trusses, as also the resultant stresses, will now be determined as previously, care being taken not to omit the quantity 2 D D_4, in computing the pull on the king post.

As an example of the application of the foregoing, let us determine the stresses on the various parts of a roof supposed to have a span of 50 feet, with a rise of 10 feet, the principals being 15 feet apart, and trussed according to the method illustrated by fig. 2. If we assume the load to be 40 pounds per square foot, we shall have $\frac{1}{4}$ w = 3·6 tons, and each lineal foot will represent a pressure of 0·36 tons. The minimum pull on the tie rod will be

$$H = 0{\cdot}36 \text{ tons} \times \frac{50}{2} = 9 \text{ tons.}$$

The maximum pull

$$H + H_2 + H_1 = 0{\cdot}36 \text{ tons} \times 50 \times \tfrac{7}{8} = 15\tfrac{3}{4} \text{ tons.}$$

The maximum pull on the braces

$$H_2 + H_1 = 0{\cdot}36 \text{ tons} \times 50 \times \tfrac{3}{8} = 6\tfrac{3}{4} \text{ tons.}$$

And the pull on the ties of the minor trusses

$$H_1 = 0{\cdot}36 \times 50 \times \tfrac{1}{8} = 2\tfrac{1}{4} \text{ tons.}$$

Which for a unit stress of 5 tons per square inch of section would give the following scantlings:—

for the middle portion of the tie rod $\frac{9}{5} = 1{\cdot}8$ sq. in. $= 1\frac{1}{2}$ in. rod.

for the ends $\frac{15{\cdot}75}{5} = 3{\cdot}15$ sq. in. $= 2$ in. rod.

for the braces $\frac{6{\cdot}75}{5} = 1{\cdot}35$ sq. in. $= 1\frac{5}{16}$ in. rod.

and for the small ties $\frac{2{\cdot}25}{5} = 0{\cdot}45$ sq. in. $= \frac{3}{4}$ in. rod.

The length of the rafter is 27 feet, and the maximum thrust on it will be

$$R + R_1 + R_3 = 0{\cdot}36 \text{ tons} \times 25 \times \tfrac{7}{4} = 17 \text{ tons.}$$

Which, for a load of 5 tons to the square inch, would give an area of $3\frac{1}{2}$ square inches. Here, however, we must remember that the rafter is not only a strut, but that it is also a beam, subject to deflection by a bending moment, whose value, in the present instance, is

$$M = \tfrac{1}{8}\tfrac{1}{4} \times 7{\cdot}2 \text{ tons} \times 25 \text{ ft.} \times 12 \text{ in.}$$

where the factor $\frac{1}{8}\frac{1}{4}$ arises from the fact of the rafter being a continuous beam, supported in three points, and whose ends cannot take any deflection. Under these circumstances, the rafter should be made subject to the condition expressed by the following formula:—

$$s = \frac{R + R_1 + R_3}{A} + \frac{M d_1}{I} \quad \ldots\ldots\ldots \quad (1)$$

where s stands for the unit strain, A the transverse area of the rafter, I the moment of inertia of the cross-section and d_1 the distance of the fibre farthest removed from the centre of gravity of that transverse section. Now rafters are generally made of two angle irons, bolted

together back to back, or of T iron, and for either of these sections we can write, with sufficient accuracy, for all practical purposes

$$\frac{I}{d_1} = \frac{1}{4{\cdot}5} A\, d$$

where d stands for the whole depth of the L or T iron.

For the case under consideration, therefore, formula (1) would read thus:

$$s = 5 \text{ tons} = \frac{17 \text{ tons}}{A} + \frac{7{\cdot}2 \text{ tons} \times 25 \text{ ft.} \times 12 \text{ in.} \times 4{\cdot}5}{64 \,.\, A\, d} \quad \ldots (2)$$

and assuming d at $5\frac{1}{2}$ inches, would give for the value of A:

$$A = \frac{17 \text{ tons}}{5} + \frac{7{\cdot}2 \text{ tons} \times 25 \text{ ft.} \times 12 \text{ in.} \times 4{\cdot}5}{64 \times 5 \times 5{\cdot}5} = 8\tfrac{1}{2} \text{ sq. in.}$$

equivalent to two L irons bolted back to back, each $5\frac{1}{2}$ in. $\times 2\frac{1}{2}$ in. $\times \frac{9}{16}$.

Professor Rankine does not caution his readers about the important fact that the rafter is to be treated as a beam subject to deflection by transverse strain, but simply makes it known as a *strut*, and defines the amount of the thrust, which, under certain circumstances, it will have to resist. The above calculation, however, shows that the area required to resist the thrust is $3\frac{1}{2}$ square inches only against 5 square inches required to resist the bending moment, and conclusively shows that a roof, calculated in strict accordance with the formulæ given by Professor Rankine, would be ridiculously deficient of strength in one of its most important parts. Possibly, however, he did not so much intend to give a theory of the stability of roofs, as to adduce examples of trussed frames of which he treats especially in that chapter; but in regard to this, we must observe that authors of his class, who are acknowledged and who acknowledge themselves leaders in mechanical science will be held responsible for any mishaps that may or shall arise from certain questions having been treated incompletely, in those of their works written for the use and guidance of practical men.

General Morin, who, among a certain class of his countrymen, has the reputation of being too careful and too heavy in his practical formulæ, strange to say, errs upon this subject in a manner similar to Professor Rankine. Starting with the correct assumption that the rafter is to be considered as an oblique beam under uniform load, and subject at the same time to a certain thrust from the reaction of the tie rod, he lays down a formula, which, containing both these elements of stress would lead to a perfectly correct result; but without any closer investigation of the subject, he then assumes it as an *a priori* fact that the element of stress, arising from the thrust, will always be so small as to be of no material consequence, and wipes out in his formula that part of it providing for the same. We have seen, however, that, in the calculations of the example chosen, the proportion of area arising from the thrust, is to that arising from the moment of flexion as 7 is to 10; and in cases where the trussing is carried still further these relative amounts would approach more and more to an equality,

plainly showing that the *a priori* assumption, upon which Gen. Morin has based his subsequent calculations, is altogether erroneous, and fraught with dangerous consequences.

We earnestly hope that this author, generally so careful and so practical, will be made alive to the error which we have just pointed out, and that before any considerable mischief is done he will revise his elaborate tables on the scantlings of rafters, for the benefit of all those whom it may concern.

(To be Continued.)

The Economic Construction of Girders.

From the Lond. Civ. Eng. and Arch. Jour., Oct., 1862.

(Continued from page 85.)

Girders of Great Spans.—The striking conclusions arrived at in our last paper will, we believe, be readily acquiesced in by those who are at the same time sufficiently acquainted with the practical requirements, and have thoroughly studied the simple mathematical questions, involved in the determination of the weights of great girder bridges. But many readers, to whom the results may be surprising and interesting, may not care to follow the processes by which these have been attained, and cannot therefore have clear impressions of the causes of such great disparities in the weights of girders when extreme spans are attempted. We shall therefore endeavor to give here a more direct and sufficiently simple exposition of the excessive influence which the value of the economic merit of any particular form of structure has upon its weight when the dimensions are greatly increased.

Familiar Exposition of the Relation between Span and Weight of Girder Bridges.—Let the general factor of safety be assumed, for the sake of simplicity, the same for all spans.

Let P represent the whole load belonging to one line of railway exclusive of the weight of the bare girders required for its support. P includes a movable loading at the rate of 1 ton per foot of span besides the weight of the shares of the roadway platform, horizontal and transverse bracings, permanent way, &c., of the complete structure, due to one line of railway.

Let G represent the weight of the bare girder or girders required to support the above loadings, besides its own weight.

Then G + P represents the whole load supported, and therefore the whole practical strength required, of the girder or girders.

Then G represents the portion of the practical strength of the girder not usefully available, being devoted to sustaining the girder itself.

And P represents the useful strength, or the portion of the practical strength available for the support of the necessary load.

Now let us assume that for a span of 50 feet the weight of the train, roadway platform, &c., or P, amounts to 65 tons; and let us suppose that two girders constructed on different systems, A and B—and each

capable of supporting, under the proper factor of safety, its own weight in addition to the above 65 tons—weight respectively 4 and 6 tons: we then have

	G + P, or Whole Practical Strength.	G, or Strength Self-absorbed.	P, or Available Strength.
Girder built on System A,	69 tons or as $17\frac{1}{4}$ to	4 tons 1 to	65 tons $16\frac{1}{4}$
Girder built on System B,	71 tons or as 11 5-6 to	6 tons 1 to	65 tons 10 5-6

Now since the weights of similar girders are as the *cubes* of their spans, while their strengths (measured by the whole of the supported loads) are only as the *squares* of their spans, it follows that the ratio of the weight of a girder to its strength, or of G : G + P, varies inversely as the span, or in other words, the ratio of G : span (G + P) is constant. Furthermore, these ratios are not materially affected by moderate changes in the absolute strength of the girders, since, within practical limits, a girder which does not vary in span, depth, or design, but only in the general scantlings or sectional areas of the parts, will have its strength varying in the proportion of its weight. Therefore if we increase the above spans from 50 to 400 feet, the ratios of G : G + P, shown above as $1 : 17\frac{1}{4}$ and $1 : 11\frac{5}{6}$, do respectively become

$$= 1 : 17\tfrac{1}{4} \times \frac{50}{400} \text{ or } 1 : 2{\cdot}16, \text{ and } 1 : 11\tfrac{5}{6} \times \frac{50}{400} \text{ or } 1 : 1{\cdot}48.$$

And the ratios of G : P will evidently be obtained by deducting a unit from each of the foregoing, or

	System A.	System B.
When G : G + P	= 1 : 2·16 and	1 : 1·48
Then G : P	= 1 : 1·16 and	1 : 0·48

Now for the span of 400 feet let us assume the value of P to be = 600 tons; and we consequently have

$$G = \begin{cases} = \dfrac{P}{1{\cdot}16} \text{ (System A.)} \quad \text{and} \quad \dfrac{P}{0{\cdot}48} \text{ (System B.)} \\ = \dfrac{600}{1{\cdot}16} = 518 \text{ tons, and } \dfrac{600}{0{\cdot}48} = 1250 \text{ tons.} \end{cases}$$

So that instead of the weights of the girders being as before in the proportion of 1 : 1·5 for the 50 feet span, they are for the 400 feet span in the proportion of 1 : 2·4, although the relative economic merits of the systems A and B remain the same as before.

The economic merit of each system may be represented by the relative value of the ratio $\frac{S\,(G + P)}{G}$; for the two systems A and B, the values of this are as 1·46 : 1, and on decreasing the spans of the girders the proportion of their weights to one another would assume more and more nearly this value taken inversely.

For a span of 500 feet, the ratios of G : G + P become

$$= 1 : 17\tfrac{1}{4} \times \frac{50}{500} \text{ and } 1 : 11\tfrac{5}{6} \times \frac{50}{500} \text{ or } 1 : 1{\cdot}725 \text{ and } 1 : 1{\cdot}183, \text{ and}$$

consequently the ratios of G : P become = 1 : 0·725 and 1 : 0·183; and if we assume P = 800 tons,

$$\text{G will become} = \frac{800}{0{\cdot}725} = 1103 \text{ tons, for the A system,}$$

$$\text{and G " } = \frac{800}{0{\cdot}183} = 4371 \text{ tons, for the B system;}$$

or in the proportion nearly of 1 : 4. We consequently have the following results :—

	System A.		System B.
Ratio of the economic merits taken inversely	= 1	:	1·46
Ratio of the weights of the girders :			
when the span is 50 feet	= 1	:	1·5
" 400 "	= 1	:	2·4
" 500 "	= 1	:	4

From the above, as from Table IV., page 84, it will at once be seen that if —from adopting a more economic design, or employing a stronger material—we can reduce the weight of a girder, taken in proportion to the load it can carry, even by what in the case of a small structure might at first sight be thought an insignificant amount, yet when a case occurs requiring a girder so great that its own weight constitutes an important portion of its load, the saving of material from that slight improvement may become immense. It is therefore an imperative duty of the engineer entrusted with the establishment of any very large structure of this class—who would not do injustice to those whose capital is embarked in the undertaking, nor bring discredit on the engineering character of his country—to search out the most economic systems of construction, and by a careful investigation, founded on the principles we have already indicated, to ascertain what materials it is best in the circumstances to employ.

Bowstring and other Girders.—There are various excellent forms of girders for which it is desirable that the values of *k* should be determined; of these we may mention the bowstring girders (see page 35), and the original design, fig. 1. We may return, on some future occasion, to the consideration of these. There is little doubt, however, that the bowstring girder, when made of sufficient depth, and also the design, fig. 1, have great economic merits. But when such forms as

Fig. 1.

these, and No. 9 of page 164,* are made use of under the ordinary arrangements, a great deal of material must be added to the upper members towards their extremities to give the necessary lateral stability, since the introduction of horizontal or transverse bracings at these parts is prevented by the position of the roadway. By modifying the arrangements, however, we may obviate this objection. Our first pro-

* Jour. Frank. Ins., vol. xliv. page 237.

posal for this purpose is, that for a double line of railway the bridge should be composed of four single girders, the two central ones being placed a considerable distance apart, as in fig. 2, this gives space for the application of continuous horizontal and transverse bracings; at the same time the amount of material E, to be added to resist the longitudinal stresses induced by the wind, is diminished on account of the increased width given to the structure; and further, the length of bearing of the transverse girders becomes reduced to a minimum.

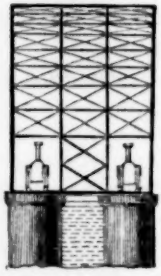
Another arrangement, which we propose as possessing some advantages, is shown in section, fig. 3.

Girder Bridges Compared with other Systems, for Great Spans.—We have treated of that branch only of the general subject of *great spans* which comes under the heading of *girder* construction, or wherein the pressures upon the supports are vertical. We do not at present purpose entering upon the other branches, which include suspension bridges and untied arched structures; but much of what we have said regarding girder bridges, and the principles of calculation we have exhibited, are equally or with slight modifications applicable to these other systems of construction; thus, for instance, formulæ 1, 2, and 3, page 21, are of universal application.

We believe that the economic advantages to be derived from the employment of the so-called *rigid* suspension bridges and united arches, as compared with properly constructed girder bridges, have been very much over-estimated: this must chiefly result from very faulty examples of girders having been chosen in drawing the comparisons.

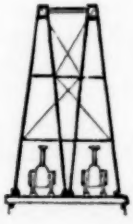
When girders such as we have pointed out are adopted, and superior materials made use of, a very low value may be assigned to k_{35}. We shall, for the sake of example, suppose this value to be = ·0007, although we have no doubt that one still lower could readily be reached by the adoption of the arrangements in figs. 1, 2, or 3, or with bowstring or other girders. The values of the parts composing F may also

Fig. 2.



End view.

Fig. 3.



Transverse section.

be considerably reduced below what are shown in Table II., page 76, on account of increased width of structure, shorter bearings for the transverse girders, and the use of steel for the ties; and for extreme spans the movable loading may be taken at less than one ton per foot

run. Under these assumptions a span of 800 feet, and that in a non-continuous structure, would be of easy accomplishment; thus, let us take—

For a Girder Spanning 800 *feet.*

E . .	=	120 tons.
H and T bracings .	=	80
Platform, &c. .	=	200
F . .	=	400
W_2 . .	=	600
$F + W_2$ . .	=	1000 tons.

And by formula (3) we have

$$G = \frac{k\,s\,(W_2 + F)}{1 - k\,s} = \frac{\cdot 56}{\cdot 44} 1000 = 1273 \text{ tons.}$$

G + E, or girders complete .	=	1393 tons.
G + F, or half of complete bridge for a double line of railway	=	1673 "

It should be borne in mind that this result, although so very satisfactory on the score of lightness, is obtained with the factor of safety taken so high as 3·5; for such spans a lower rate of strength would be sufficient according to some authorities. We venture then to think that the girder system, when its combined advantages of rigidity and facility of erection are taken into account, will contrast favorably in a general point of view with any other system of construction, even for such spans as 700 or 800 feet. Its rigidity gives it a favorable distinction from the suspension system; while its facility of erection will in most situations prove an advantage over the arch.

The suspension bridge if thoroughly braced, and when the cost of the *land chains* and that of the heightened towers are included, will not probably be much, if any, cheaper than the best girder one, especially if, as would probably be the case, a higher factor of safety were insisted upon for the former than for the latter. In some situations indeed, as when an unnavigable torrent of great width has to be crossed, the suspension principle is the only feasible one.

The untied arch must ever have a great excess of sectional area, or a large addition of material to stiffen and brace it, which will greatly reduce its economic merit; a centring being required for its erection, will also in many situations prove almost a barrier to its use.

If it be desired, instead of employing a general factor of safety = 3·5 as in the above calculation, to have a higher factor (say = 4·5) for the movable portion of the loading, and the ordinary value = 3 for the fixed loading; all we have to do is to substitute for W_2 the value of $\frac{4\cdot5}{3\cdot0} W_2$, and make use of 3 as the *general factor*, and instead of $k_{3\cdot5} = \cdot0007$ to employ $k_3 = \cdot0006$: thus,

$$G = \frac{\cdot0006 \times 800}{1 - \cdot0006 \times 800} F + \frac{4\cdot5}{3\cdot0} W_2 = \frac{\cdot48}{\cdot52} 1300 = 1200 \text{ tons.}$$

G + E, or girders complete	= 1320 tons.
G + F, or half of complete bridge for a double line of railway	= 1600 "

The results being somewhat less than when the general factor 3·5 is used.

Approximate Comparison of the Weights of Plate and Open-work Girders for Various Proportions of Depth to Span.—Whether the web of a girder be made of plate-work or open-work, the sum of the weights of the top and bottom may be set down as the same.*

Now we found that when S ÷ D = 8, the weight of the bracing of an open-work girder was equal to half the weight of the booms; and that its weight was nearly constant, although the depth of the girder underwent considerable changes. Other things equal, we may take the weight of the booms in both systems as inversely proportional to the depth, or as S ÷ D.

In the plate system, we believe, we do not overstate the case when we assume that the weight of the sides will vary nearly in proportion with the depth of the girder; this takes for granted that any saving that can be secured from thinning the plates of the sides when the depth is increased, will be fully absorbed in necessary additions to the sections of the L and T irons to give the requisite lateral stability and stiffness.

In the Conway tube the weight of the sides is equal to half that of the booms, and we have shown that S ÷ D is fully equal to 18, but as we do not wish to be chargeable even with not favoring the plate form, we will call this = 16. From these data, and taking the value of S ÷ D to represent the weight of the booms, we at once obtain the results in the following table:—

Proportion of Span to Depth, or S ÷ D.	Total and partial Weights of the Girders, when the same load is supported.							
	Open-work Girder.				Plate-work Girder.			
	Booms.		Web.	Total.	Booms.		Web.	Total.
32	32	+	4 =	36	32	+	4 =	36
28	28		4	32	28		4·57	32·57
24	24		4	28	24		5·33	29·33
20	20		4	24	20		6·4	26·4
16	16		4	20	**16**		**8**	**24·0**
12	12		4	16	12		10·67	22·67
8	**8**		**4**	**12**	8		16	24
4	4		4	8	4		32	36

* This ignores the moments of the longitudinal stresses of the plates of the web; against these may be placed the fact that the lower boom of an open-work girder may be made stronger for its weight than the corresponding boom of a plate girder. Where, however, the depth is great in proportion to the span, these moments may become of such importance as to require account being kept of them; the effect being to reduce somewhat the weight of metal in the booms of such girders. The late Mr. Robert Stephenson seems to admit that in ordinary cases at least, these moments should not be counted upon, as we find at page 597, article "Iron Bridges," in the 8th edition of the "Encyclopædia Britannica," these words: "The central strain on the top and bottom flanches, which depends solely on the depth of the girder, and is perfectly independent of the system which connects them. . . . . "

This table, although professedly only a rough approximation, offers many interesting points of comparison, several of which give us confidence in its contents not being very far from accurate.

We may take the weights given in larger type as practically correct. Those for the webs of the shallower girders of the open-work character are probably overstated, so that it is for the last example only that any economic exaggeration can exist. In the plate girders there may be room for more doubt, but the fact of the minimum weight for these pointing to the proportion of 1 : 12 as the most economical for that of the depth to the span is important, since if we are wrong in our views regarding the increase in the weight of the web—and it should really not increase in weight so rapidly as the depth—then the girder of minimum weight would result from a still higher proportioned depth than one-twelfth, which would stultify the practice of the advocates of this mode of construction. One-twelfth of the span is the greatest depth for large plate girders that would probably be attempted. There may, however, arise subordinate questions here,—viz: that the economic laws governing the ratios of span to depth (for plate girders especially) may not be constant for different spans, and that for a short girder a higher value of the depth may be resorted to. Various reasons could be adduced in support of this, besides that of every-day practice.

We may further notice that in the above table the girders become equally economic when the depth is made equal to the span divided by 32, or about half the proportional depth of the Conway. For depths less than this the economic merit would be on the side of the plate system; this value, 32, is that of the x contained in the article at page 236 of vol. xvii, of this Journal. R. H. B.

Edinburgh.

International Exhibition.

From the Mechanic's Magazine, December, 1862.

CLASS X, SECTION A—JURORS' REPORT.

JURY.

A. Bommart, France; General Inspector in the Imperial Corps of Bridges and Roads.
J. Kelk, London; Contractor.
Koch, Zollverein; Government and Architectural Councillor, Berlin.
J. Leclerc, Belgium; Inspector of Agriculture and Engineer of Bridges and Roads.
Maurice Loehr, Austria; Imperial Councillor of the Board of Trade and Public Works.
C. Manby, F.R.S., London; Hon. Sec. to the Institute of Civil Engineers.
Thomas Page, London; Civil Engineer.
Sir J. Rennie, F.R.S., F.G.S., President of Section, London; Civil Engineer.
Marquis of Salisbury, K.G., Chairman, London.
Cesare Valerio, Italy; Member of the Italian Parliament.

ASSOCIATES.

Baron Baude, France; Engineer to the Imperial Corps of Bridges and Roads.
Mille, France; Engineer-in-Chief of Bridges and Roads.

—

I. *Bridges.*—There are few more important and difficult operations in civil engineering than the construction of bridges across great rivers, estuaries, and valleys, and none which require greater skill and

judgment in design and construction, in order that the works may be properly adapted to fulfil the object in view in the best manner and at the least possible cost; and, it is but justice to say, that amongst the numerous objects of this class submitted to our examination, there are works of the highest merit, and which have been most successfully carried into effect.

Amongst the most prominent and important of this kind may be mentioned the class of wrought-iron tubular girder bridges exemplified by the remarkable and extensive bridge erected across the river St. Lawrence, at Montreal, for the Grand Trunk Railway in Canada. This bridge was based upon the system introduced in the "Conway" and "Britannia" bridges, on the Chester and Holyhead line of railway.

All these three bridges were designed by and constructed under the direction of the late Robert Stephenson, M. P., F. R. S., and both he and the resident engineers and contractors are entitled to the greatest possible credit for the novelty, originality, and boldness of the designs, the admirable and ingenious contrivances employed in the structures as they have been carried into effect, as also for the very complete manner in which they have answered the objects for which they were designed and constructed, so as to offer the least possible obstruction to the navigation, and at the same time to afford the greatest and most substantial accommodation to the traffic passing over them. They were necessarily attended with great practical difficulties in the execution, not only in combining and putting together the vast masses of wrought iron, rarely before attempted upon such a great scale, but also in the planning and construction of the foundation and the masonry piers, particularly in those of the "Victoria" bridge, across the St. Lawrence, where special provision was necessary for resisting the pressure of the immense masses of floating ice set in motion on the breaking up of the frost at each spring. For the foundation of these piers and ice-breakers, Mr. Hodges, the engineer of the contractors, devised a most ingenious system of movable coffer-dams, which answered admirably, and to him, as to Sir Morton Peto, M. P., Mr. Brassey, and Mr. E. L. Betts, the enterprising contractors for the works, the utmost credit is due for the successful manner in which the great difficulties were met and overcome, and for the general successful result of their work. It is not necessary to describe these great works in detail, as this has already been done in the masterly and elaborate description of the Conway and Britannia bridges by Mr. Edwin Clark, and Messrs. Peto and Betts, and Mr. Hodges in the description of the "Victoria" bridge; to which works, those who take an especial interest in these important subjects are more particularly referred.

To Mr. G. R. Stephenson, as the representative of his cousin, the late Mr. Robert Stephenson, M. P., F. R. S., has been awarded a medal for the extraordinary boldness of conception and the great ingenuity of the construction; and to Sir S. Morton Peto, Bart., M. P., Mr. T. Brassey, Mr. E. L. Betts, and Mr. J. Hodges, a collective honorable mention, for the successful execution of this bridge, and for

the ingenuity displayed by Mr. Hodges in the construction of the cofferdams.

Next, and scarcely inferior in importance to the above mentioned bridges, may be mentioned the bridge across the Wye, at Chepstow, and the "Albert" bridge over the Tamar, at Saltash, both designed by, and constructed under the direction of, the late Isambard Kingdom Brunel. These are of a somewhat different character, being a combination of a wrought iron superstructure with cast iron columns, the arrangement being upon the insistent and the suspension principles combined.

It may be a question whether one of these systems, particularly the insistent principle alone, if properly applied, of the requisite dimensions, would not have been as efficient, simpler, and better calculated to have answered the object in view: nevertheless, these two bridges have been extremely well designed and constructed, and they practically fulfil their object most successfully. The foundation of the great central, or deep-water pier, in the Tamar, for the Saltash bridge, was a most difficult and hazardous undertaking, as it was necessary to carry it down through a depth of water of 82 feet at high water, with a rise of 18 feet of tide. This foundation was carried down through a bed of soft mud, nearly 16 feet thick, to the solid rock, which was effected by means of a wrought-iron cylinder of 37 feet diameter and 90 feet in height, which was forced down to the bottom partly by insistent weight, and partly by means of atmospheric pressure. The proceedings were so well arranged that little hazard was incurred, and the works of sinking the cylinder, constructing the masonry foundation, erecting the iron columns upon it, and lifting the tubes, were most successfully accomplished. In connexion with the execution of this work, Mr. Brereton, the chief assistant of Mr. Brunel, should be mentioned as having carried out the views of the engineer most efficiently. To Mr. Isambard Brunel, as the representative of his father, the late Mr. I. K. Brunel, F. R. S. (United Kingdom, 2245), has been awarded a medal, for the boldness of design and for ingenuity and goodness of construction, and for the novel and excellent method of sinking the foundations of both these bridges.

The next work of this class is the lattice bridge across the river Boyne, at Drogheda, on the line of the Dublin and Belfast Railway. It was designed by and constructed under the directions of Sir John Macneill. It is upon the lattice principle of wrought iron, and is by far the largest structure of the kind which has hitherto been erected in the United Kingdom. The invention, or rather the first great application of this class of bridge, may be said to have taken its origin in the United States of America, where such structures of timber have been employed to a great extent. The merit of their introduction into Great Britain in the form of wrought iron may be attributed to Sir John Macneill, and they are now largely employed on the Continent, and indeed all over the world. They come under the class of girder bridges, and their chief merit may be said to consist in their lightness and economy, consistent with a proper degree of strength. The bridge

over the Boyne, above mentioned, as well as another upon the same principle across one of the public streets at Dublin, upon the same line of railway, are extremely well designed and constructed, and are excellent examples of the kind, and as such are entitled to a considerable degree of credit.

To Sir J. Macneill, F. R. S. (United Kingdom, 2316), has been awarded a medal for the importance of the design and the successful execution of this bridge; in which he received very efficient co-operation from James Barton, resident engineer.

Several large bridges upon the same principle have been designed by, and constructed for, Lieut. Col. Kennedy, upon the line of the Bombay and Baroda Railway, India. The piers of these bridges are formed by means of Mitchell's cast iron screw piles, firmly fixed in the bed of the river, and properly braced together by wrought iron ties. These structures have not any pretensions to originality, but they are remarkable for the simplicity and economy of their construction, for their successful completion, and for their completely answering the object for which they are intended. To Lieut. Col. Kennedy (United Kingdom, 2307) has been awarded a medal for the extensive application of screw-piles to bridges in India.

To Messrs. Gilkes, Wilson, and Co. (United Kingdom, 2290), has also been awarded a medal for the excellence of execution of the iron railway viaduct, with cast iron diagonally braced piers, erected by them over the river Belah, from the designs and under the direction of Mr. Bouch.

In connexion with this branch of engineering, a medal has been awarded to Mr. E. C. E. Dapples, of Lausanne (Switzerland, 127), for an ingenious modification of the screw-pile shoes for timber or iron piles.

Next must be mentioned the bridges, models of which are exhibited (under the No. 1251, in the French Catalogue) by the Minister of Agriculture, Commerce, and Public Works of France, whose liberality in collecting and transmitting to this country so excellent a collection of models of interesting works cannot be too highly eulogized. Many of these bridges are remarkable for the ingenuity and boldness of their design, and for the very successful manner in which they have been carried into effect.

First amongst these may be mentioned the great Turning Balanced Bridge across the Penfeld, a creek connected with the naval arsenal of Brest; this structure is by far the largest of the kind that has ever been attempted, and as such requires particular notice. It is composed wholly of wrought iron, with the exception of the counterbalance weights, which are of cast iron. The total width of the opening, or clear space between the two circular piers, or abutments on the opposite shores, is 106 metres. The bridge itself consists of two equal portions, which meet in the centre, at an elevation of 19½ metres above the level of high tide, each being supported on either side by a massive circular tower of granite masonry, upon which they revolve on a series of cast iron rollers, in a massive iron frame, which

is made to rotate by means of a system of wheel-work, worked from the top by two men for each half, by whom, in calm weather, the operation of opening and shutting the bridge is performed in about fifteen minutes.

When the bridge is closed it is fixed in its place by means of self-acting keys, which are easily detached when it is required to open it for the passage of full sized vessels.

The total width of the roadway, including that for the carriages as well as for the foot passengers, is 7¼ metres.

The ends between the piers and the abutments, at the adjoining streets, are filled with the counter-balance weights, which are so regulated as to balance the other two and longer portions, between the piers and the centre or the opening, so perfectly as to enable the rotation to be effected with the least possible friction; and in order to afford ready access for repairs to the rollers, arrangements are made for lifting the entire ring, by hydraulic pressure, within a few minutes.

This bridge may be said to fulfil its purpose admirably, and whilst it forms a convenient and much required communication between the towns of Brest and Récouvrance, which are situated on either side, it affords free passage for vessels of war under and through it, in consequence of its great height from the surface of high-water to the under side of the arch.

The original project for this great work is due to Messrs. Cadiat and Oudry, to whom a collective medal has been awarded as the authors of the original project, and for its boldness and unique character; but the actual structure was designed and constructed by M. Mathieu, the able engineer of the Creusot Iron Works, and by Messrs. Schneider and Co., who were the contractors for the work. The erection of the structure was superintended by Messrs. Matrot de Varennes and Aumaitre, engineers-in-chief of bridges and roads, and M. Rousseau, engineer.*

The next bridge most worthy of remark is that erected over the valley of the Sarine, on the line of the Fribourg and Lausanne Railway. It was designed and constructed by M. Mathieu, the engineer for the Creusot Company, who were the contractors for the work, and at whose establishment it was all manufactured.

The total length of this bridge is nearly 329 metres, and it consists of seven openings, of nearly 49 metres each, supported upon 6 cast iron piers, composed of diagonal-framed panels, firmly braced together by wrought iron rods placed diagonally. The openings are spanned by wrought iron girders, upon the trellis principle; the highest pier in the deepest part of the valley being 80 metres in height, of which the upper length of 44 metres is in metal, so that in point of economy it became an object of the greatest importance to avoid the construction of scaffolding, which would have been attended with considerable expense; this was happily effected by a very ingenious and novel system.

*It would have been proposed to award a medal to M. Mathieu for this important work, but it was reserved for the design and execution of the Bridge of Fribourg, which are scarcely, if at all, less ingenious and successful than those of the Bridge of Brest.

The lattice girders, with the platform forming the whole width of the bridge, were, in the first instance, constructed; or put together on one of the adjoining abutments, and placed upon rollers, over which they were drawn forward until the end overhung the position at the first pier, having sufficient counterbalancing weights at the ends to prevent them from falling as they were moved onward. As a further precaution against this danger, the ends were stayed by chains and rods of wrought iron, attached to strong derricks, or cranes fixed upon the piers, provided with proper machinery for hauling them along, so that in proportion as they advanced the chains were shortened, until the ends of the girders reached the point over each pier. The panels for forming the pier were then brought forward upon the girders and platform, and were lowered to their position; so that the structure, in fact, grew up beneath the girders, which were then again drawn forward over the piers, and the same process was repeated until the whole bridge had been drawn across, when the platform was securely fixed in its position. By means of this novel, simple, and ingenious contrivance, this bold and economical railway bridge, or viaduct, was most successfully constructed, to the great credit of the Creusot Iron Company and their able engineer-in-chief, M. Mathieu, inventor of the method of construction and builder of the bridge, to whom the jury have awarded a medal, with the expression of their highest satisfaction for the invention and successful application of the method employed in the construction; and they thought it right to give an honorable mention to M. Clerc, for the excellence of the model of the bridge, exhibiting the mode of construction.

A road bridge, called the "Pont de St. Just," across the mountain torrent, the Ardeche, upon the same principle, with stone piers, was designed originally by M. Oudry, and constructed by the Creusot Iron Company, under the immediate direction of M. Mathieu, with equal success. This bridge, which consists of six spans of 46·26 metres each, was also remarkable for the obstacles encountered, not only in constructing the piers, in consequence of the extreme violence of the torrent during floods, but because it was absolutely necessary to provide a means of placing the wrought iron arched girders, without having recourse to the ordinary mode of fixing scaffolding beneath. This was accomplished by having a counterbalanced scaffolding, which was propelled forward from the abutment over the piers consecutively, having on it the means of raising the arched iron girders to their places on the piers. This was very successfully accomplished, without accident; and the award of a medal would be justly due to M. Mathieu, the engineer-in-chief of the Creusot works, to whom were entrusted all the details of the construction of this work, if he had not gained one for the bridge of Fribourg.

The next viaduct bridge worthy of remark is that over the Rhine, at Kehl, for connecting the Eastern Railway of France with the German system of railways at Strasbourg.

The execution of this great work was, by mutual consent, apportioned between the engineers of the Eastern Railway, who undertook

the construction of the foundations and the piers, and the engineers of the Grand Duchy of Baden, who were charged with the execution and fixing of the superstructure. The foundations and the mode of executing them were designed and executed by M. Vuigner, engineer-in-chief, and Monsieur Fleur-Saint-Denis, resident engineer, with M. de Sappel, acting engineer; and their designs were carried into effect with great intelligence by the enterprising contractors, Messrs. Castor.

The general features of this viaduct are, masonry piers, supporting a superstructure of wrought iron girders, on the trellis principle, with a lifting, opening at each extremity, to permit the passage of the masted vessels which navigate the Rhine.

The principle difficulties in the construction of this bridge arose from the depth of the river, the rapidity of the current, and the shifting nature of the bed, which, being composed of loose gravel, was at times scoured away to the depth of many feet; so that no bridge could be rendered permanent, unless the foundations of the piers were carried down to a depth below the action of the current. In order to effect this it was necessary to resort to extraordinary measures. This was effected by the employment of large wrought iron caissons, placed side by side, so as to cover the entire space of the pier. These contained air cylinders, with valves in them rising from the top of the caissons to above the level of the water, and a large cylinder, open at both ends, having its lower extremity descending below the edges of the caisson. Within this latter cylinder was fixed a dredging frame and buckets.

(To be Continued.)

Prime Movers.

From the London Artizan, December, 1862.

The unit of work is one horse power, or 33,000 lbs., raised one foot per minute.

Let P represent the actual pressure of steam per square inch on the piston, p the resistance per square inch, caused by the exhaust steam on the opposite side of the piston, both in pounds, N the number of strokes per minute, and l the length of the stroke in feet, and a the area of the piston; then, if we represent the actual horse power by H a,

$$\text{H } a = \frac{(\text{P} - p)\ a.\ l.\ \text{N}}{33000}$$ which is the work done upon the piston.

To ascertain the mean pressure upon the piston, indicators are connected with the top and bottom of the cylinder, which register the pressure at every part of the stroke, from which register the mean pressure may be found; the diagram drawn by the indicator is also valuable as showing accurately the action of the slides.

The nominal horse power of an engine is usually far less than the actual horse power, being determined by a measurement of the cylinder without regard to the pressure at which it is intended to be worked, although a pressure is determined upon which the formula depends,

thus for condensing engines the value of $(P - p)$ is very generally taken at 7 lbs.

The nominal horse power provides the data by means of which engines may be compared as to commercial value, the price being usually fixed at per horse power.

The following are some of the formulæ used for determining the nominal horse power of engines,—

a = area of piston in square inches.

d = diameter of piston in inches.

H n = nominal horse power.

Condensing Engines.

Watt's Rule. $\text{H } n = \sqrt[3]{\text{stroke} \times d^2}$

Manchester Rule. $\text{H } n = \frac{a}{23}$

Leeds Rule. $\text{H } n = \frac{d^2}{30}$

Non-Condensing Engines.

Manchester Rule. $\text{H } n = \frac{a}{10}$

Leeds Rule. $\text{H } n = \frac{d^2}{16}$

The power of steam boilers may be safely calculated at one horse power for every square yard of heating surface and square foot of fire surface, this being sufficient to evaporate one cubic foot of water per hour. For cylindrical boilers, with the fire underneath, the horse power is equal to one-fifth the horizontal section; or if

l = length in feet,

d = diameter in feet,

$$\text{H} = \frac{d\,l}{5}.$$

If there are flue tubes as well, their section must be added to that of the boiler.

The efficiency of vertical heating surface is only half that of horizontal surface above the fire.

With regard to the capacity of boilers, 27 cubic feet per horse power is economical.

The Lancashire rule allows one cubic foot of boiler room for every square inch of piston.

The North Country rule allows a cubic foot of boiler room for every circular inch of piston.

Water Wheels.

Let Q = the quantity of water supplied per second, in cubic feet.
w = the weight of a cubic foot.
V = the supply velocity, in feet per second.
v = the discharge velocity, in feet per second.
h = the difference of head of water before and after its action on the wheel, in feet.
N = the number of pounds raised one foot per second.

The total energy of the water is,

$$N = Q w \left\{ h + \frac{V^2}{2g} \right\}$$

the energy of the water when discharged,

$$N = Q w \frac{v^2}{2g}$$

the power impressed upon the wheel,

$$N = Q w \left\{ h + \frac{V^2 - v^2}{2g} \right\}$$

$$h + \frac{V^2}{2g}$$

represents the theoretic head which we will call h_1,

The limit to the efficiency of the machine is evidently,

$$Q w \left\{ h + \frac{V^2}{2g} \right\}$$

but it is usually far removed from this.

We will represent the co-efficient for reducing the total power of the water to the available power by c; then calling H the horse power of the machine, $H = 0{\cdot}1227 \,.\, c \,.\, Q h$.

The usual velocity of overshot and breast wheels is from three to six feet per second.

Turbines are usually of small diameter; they work under great heads; one erected at St. Blasien working under a fall of 354 feet, producing 0·75 of the power expended upon it, it would make 2300 revolutions per minute. Turbines seldom have a velocity less than one-half or one-third of that due to the fall.

The values of c for the various forms of water wheel are as under—

Breast wheels, Overshot wheels	0·75 to 0·85
Undershot wheels, radial floats,	0·30
Undershot wheels, curved floats,	0·60
Turbines,	0·70 to 0·90

Iron Pipes for Railway Bridges in Alluvial Districts.

From the Lond. Civ. Eng. and Arch. Journal, Sept., 1862.

Conspicuous among the British Engineering Models at the International Exhibition may be observed Colonel J. P. Kennedy's models and drawings (2307, Class 10), illustrating "the Finance of Railways and other public works." Of these the most copious and important subject relates to the construction and erection of iron piers and superstructures for railway and other bridges and viaducts in alluvial districts. The results are derived from the system which he has adopted on the Bombay and Baroda Railway. That system has been already noticed in this Journal (vol. xxiv., p. 251), to which we beg to refer our readers. It is well adapted to the requirements of the colonies, in consequence of its economy in first cost, facility of transit in long voyages and of erection in situations where the supply of skilled labor and mechanical appliances are very limited.

The practice held forth is based upon the erection of 95 bridges across rapid rivers, most of them tidal, and flowing upon alluvial beds; the aggregate length of bridge-work being about 6¾ miles. The length of line conceded for construction was 313 miles, of which about two-thirds are finished, and the balance is on the eve of completion. The financial powers of this line may be estimated from the unprecedented fact that single engines, four wheels coupled, have hauled along its entire length, and in each direction, trains of 72 carriages, conveying 4000 passengers at the regulated speed of 20 miles an hour. Colonel Kennedy, from the outset of his operations, has aimed at securing low fares for his passengers, with high dividends for his shareholders. He expects that the cost of the line shall not exceed £11,000 per mile, notwithstanding its difficult character and the antagonism with which he has had to deal.

The extent of country to be supplied by railways in India is very great, averaging 1000 miles across from west to east, and more than double that distance from north to south. It is intersected by two principal ranges of mountains; the Vindea central range running from west to east, and the Syhadree range, 2000 feet high, running from the centre of India southwards along the west coast, with a steep declivity towards the sea on the western side, but a gradual fall inland on the eastern. In the case of the Bombay and Baroda line great care was necessary in surveying the country beforehand, to make sure that all branch lines intended to be constructed afterwards would be practicable, and 4000 miles of ground were examined before any steps were taken in commencing the works: this was the more important in so mountainous a country, in order to get the best possible levels along the entire course of the line, and the result was a ruling gradient of 1 in 500. The population of the country and its capabilities of supplying produce are so great as to ensure an enormous traffic for all the railways, and financial difficulties alone have hitherto retarded the progress of railways. The vast importance of ready communication through India may be judged of from the fact that India already consumes a larger amount of British produce than any other country;

hence it is that, while her colonies are the main support of the industrial classes at home, England must look to her colonies and to India especially for the maintenance and advancement of that industry; and facility of road traffic is therefore essential for increasing the demand for home productions and for returning larger supplies of raw material.

From the nature of the country it frequently occurs in India that the practicability of building a bridge in a particular locality is the consideration which determines whether there should be a road or not; and the same condition decides the question also as to a railway. The large majority of the lines have to follow the valleys and to cross the rivers frequently, requiring a special construction of bridge piers for the alluvial soil, where solid masonry piers are most costly if not impracticable. The piers are thus of vital importance: many kinds of superstructure may be adopted, but on the piers depend the practicability of making the railway. On the Indian lines miles of bridges have to be dealt with, which must be strong enough to withstand the fierce monsoon floods running at 6 to 10 miles per hour. Hence great strength and durability are necessary in bridge piers, combined with cheapness of construction; otherwise a railway could not be attempted with any prospect of a successful issue.

The piers are composed of hollow cylindrical cast iron piles, of 1 inch thickness of metal and 2 ft. 6 ins. outside diameter, cast in 9 feet lengths, weighing about 1½ tons each; these are of two principal patterns, for the portions of the piles above and below the ground. That above the ground, has flanches outside for bolting the lengths together by twelve 1-inch bolts; while that underground has the flanches inside bolted together by ten 1-inch bolts, and is flush on the outside so as to offer no resistance in penetrating the ground; they are large enough inside to leave room for a man getting in to bolt the several lengths together properly in the process of erecting. The foundation is obtained by one of Mitchell's screws at the bottom of each pile, of 4 ft. 6 ins. diameter, which finds its own foundation without the expense of coffer-dams or any other artificial preparation of the ground. The upright piles are placed 14 feet apart from centre to centre, and are sunk to a depth of about 20 feet in the ground; but where the ground is softer than usual they are carried down deeper, to obtain the requisite strength of foundation. The greatest length of pile used has been 45 feet below the ground and 72 feet above. The oblique piles forming the struts are inclined at an angle of about 30° to the upright piles; they are precisely the same in construction as the upright piles, and are joined to the latter at about the ordinary flood level by a cap cast at the proper angle, which clips the body of the upright pile. The piles are all connected together above ground by horizontal and diagonal wrought iron bracing, attached to lugs cast on the piles by a pin at one end and a gib and cotter at the other. The several parts of the bracing act alternately as struts and ties according to the direction of the current, and in consequence of this alternate strain an accurate fit of the bracing is required; to insure this the joints at one end of each are therefore left to be done in India from measurement on the

site, this being the only forging required in India. A party of submarine fitters is employed for attaching the bracings to the pilings and other work under water. These men are furnished with Heinke's helmets and dresses. The outside piles are faced with a double row of timber as a fender to protect them against shocks from anything floating in the water and brought down by the current. The weight of a single complete pier of five piles for two lines of rails, 63 feet high from the foundations, is 75½ tons, and the cost £624, delivered in London.

This form of girder, when manufactured and accurately fitted in England, requires the smallest amount of skilled labor for its erection abroad on reaching its destination; only a few pins and bolts have to be put in for completing the girders, and the skilled labor required for riveting box girders or lattice girders is avoided.

(To be Continued.)

On the Strength of Long Pillars. By B. B. Stoney, B. A.

From the Lond. Pract. Mechanic's Jour., Dec. 1862.
[Read before the Royal Irish Academy, June 23, 1862.]

Among the numerous difficulties encountered in designing large iron structures, such as railway girders or roofs of large span, none perhaps is of more importance, or requires greater skill to overcome, than the tendency of parts under compression to deflect beneath the pressure, and yield sideways, like a thin walking-cane, when the load is greater than it can support without bending.

To understand the matter clearly, we must recollect that the mode in which a pillar fails varies greatly, according as it is long or short in proportion to the diameter. A very short pillar—a cube, for instance—will bear a weight sufficient to splinter or crush it into powder; while a still shorter pillar—such as a penny, or other thin plate of metal—will bear an enormous weight, far exceeding that which the cube will sustain, the interior of the thin plate being prevented from escaping from beneath the pressure by the surrounding particles. We can thus conceive how stone or other materials in the centre of the globe withstand pressures that would crush them into powder at the surface, merely because there is no room for the particles to escape from the surrounding pressure.

It has been found by experiment that the strength of short pillars of any given material, all having the same diameter, does not vary much, provided the length of the pillar is not less than one, and does not exceed four or five diameters; and the weight which will just crush a short pillar, one square inch in section, and whose length is not less than one or greater than five inches, is called the *crushing strength* of the material experimented upon. If the length of pillars never exceeded four or five diameters, all we need do to arrive at the strength of any given pillar would be to multiply its transverse area in square inches by the tabulated crushing strength of that particular material. It rarely happens, however, that pillars are so short in proportion to their width; and hence we must seek some other rule for calculating their strength, when they fail, not by actual crushing, but by flexure.

If we could insure the line of thrust always coinciding with the axis of the pillar, then the amount of material required to resist crushing merely would suffice, whatever might be the ratio of length to diameter. But practically it is impossible to command this, and a slight deviation in the direction of the thrust produces a corresponding tendency in the pillar to bend. With tension-rods, on the contrary, the greater the strain, the more closely will the rod assume a straight line, and, in designing their cross section, it is only necessary to allow so much material as will resist the tensile strain. This tendency to bend renders it necessary to construct long pillars, not merely with sufficient material to resist crushing, supposing them to fail from that alone, but also with such additional material or bracing as may effectually preserve them from yielding by flexure. It is evidently, therefore, of considerable importance that we should ascertain the laws determining the flexure of long pillars, which may be done as follows:—

Let the figure represent a pillar, very long in proportion to its breadth, and just on the point of breaking from flexure.

Let W = the deflecting weight;
b = the breadth of pillar;
d = its depth;
l = its length;
h = the central deflection;
R = the radius of curvature;
C = the resultant of all the longitudinal forces of compression on the concave side at the centre of the pillar;
T = the resultant of all the longitudinal forces of tension on the convex side;
δ = the distance between the centres of tension and compression.

The longitudinal forces acting at the centre of the pillar are three, viz.: the weight, W, acting in the chord line of the curve, the resultant, C, acting at the centre of compression in the concave half, and the resultant, T, acting at the centre of tension in the convex half. Taking moments round either centre of strain, we have approximately

$$W \frac{T\delta}{h} = \frac{C\delta}{h}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad 1.$$

h being assumed equal to the distance between the chord-line and either centre of strain, which is a close approximation when the pillar is very long in proportion to its width.*

The values of T or C in different pillars are proportional to the number of fibres subject to strain, that is to $b\,d$, and δ is obviously proportional to d; so that we have the numerator on the right side of the

* Mr. Hodgkinson's experiments show that this investigation is not applicable to cast iron pillars whose length is less than about 30 times their width: even with such short pillars it requires certain modifications, which he has deduced from experiment.

equation proportional to $b\,d^2$. Again, assuming that the deflection curve is a parabola, from which it can differ but slightly,* we have

$$h = \frac{l^2}{8\,\mathrm{R}};$$

but so long as the strain per sectional unit in the extreme fibres, to which their change of length is proportional, is constant, R will vary in the same ratio as d; and we have, therefore, h, proportional to

$$\frac{l^2}{d}.$$

Whence, by substitution,

$$\mathrm{W} = \mathrm{K}\,\frac{b\,d^3}{l^2}, \qquad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad 2.$$

in which K is a constant depending on elasticity of the material, which may be determined by experiment.

If the pillar be round, and if d represent the diameter,

$$\mathrm{W} = \mathrm{K}\,\frac{d^4}{l^2}, \qquad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad 3.$$

which proves that the strength of long round pillars varies as the 4th power of their diameter, divided by the square of the length; and the longer the pillar is in proportion to its diameter, the nearer will this formula represent the truth.

As all the longitudinal forces at the middle of the pillar balance, we have the following equation:—

$$\mathrm{C} = \mathrm{T} + \mathrm{W},$$

which enables us to predict how a long pillar will fail, whether by the convex side tearing asunder, or by the concave side crushing. A wrought iron pillar, for instance, may be expected to fail on the concave side, as its power to resist crushing is less than that to resist extension. A long pillar of cast iron, on the contrary, will probably fail by the convex side tearing asunder, as the compressive strength of cast iron greatly exceeds its tenacity. Further, the effective strength of wrought iron to resist crushing is about 12 tons per square inch, while the tensile strength of cast iron is nearly 7 tons per square inch; and hence we may conclude that the strength of long similar pillars of wrought and cast iron will be nearly as 12 to 7.

It is also worthy of note that, if the same pillar be bent in different degrees, T will vary as h, while δ remains constant; whence it follows from equation (1) that W, the weight which keeps the pillar bent, is nearly the same whether the flexure be greater or less. This statement would be accurately true, were it not that equation (1) on which it is founded, is only approximate. It will, however, agree very closely with experiment so long as h is considerable, that is, whenever the flexure is not slight. From this it follows, that any weight which will produce considerable flexure will be very near the breaking weight, as a trifling addition to it will bend the pillar very much more, and strain the fibres beyond what they can bear.

* The curve will probably be intermediate between a parabola and a circle, approaching the latter if the pillar taper towards the ends.

MECHANICS, PHYSICS, AND CHEMISTRY.

For the Journal of the Franklin Institute.

Notes of Shipbuilding and the Construction of Machinery in New York and vicinity.

(Continued from page 45.)

The Steamer Cosmopolitan.—Hull built by John Englis, Greenpoint, L. I. Machinery constructed by Morgan Iron Works, New York. Owners, Sanford's Independent Line. Route of service, New York to Havana.

Hull.—Length on deck, 220 ft. Breadth of beam, 30 ft. 8 ins. Depth of hold to spar deck, 12 ft. Draft of water, 6 ft. Rig—schooner. Tonnage, 800 tons.

Engines.—Vertical beam. Diameter of cylinder, 50 ins. Length of stroke of piston, 11 ft.

Boilers.—One—flue—located on deck, and uses a blower.

Paddle Wheels.—Diameter over boards, 31 ft. Material, wood. Have water-wheel guards fore and aft.

Remarks.—This vessel is of white oak and chestnut, and put together and braced in the most thorough manner. Its whole construction adds much credit to the excellent mechanical reputation of its builder.

The Steamer Po-Yang.—Hull built by Roosevelt, Joyce & Co., New York. Machinery constructed by Allaire Works, New York. Owners, Olyphant & Son, New York. Route of service, coast of China.

Hull.—Length on deck, 220 ft. Breadth of beam, 30 ft. Depth of hold, 11 ft. 6 ins. Draft of water, 7 ft. Frames—molded, 14 ins.—sided, 6 ins.—apart at centres, 18 to 28 ins. Tonnage, 756 tons.

Engines.—Vertical beam. Diameter of cylinder, 50 ins. Length of stroke of piston, 12 ft.

Boilers.—Two—return tubular—located in hold. They are constructed of the best material and are of the most durable character.

Paddle Wheels.—Diameter over boards, 28 ft. Material, iron.

Remarks.—This vessel is of extraordinary strength, her materials being live oak, chestnut, &c. She is fastened with copper and tree-nails; and around her frames—iron straps, diagonal and double laid, 3½ by ⅝ inches—are placed, making them very secure. Her rig is that of a foretopsail schooner; her bunkers are of wood, and she has an enclosed forecastle, but no sponsons under water-wheel guards. She has two water-tight bulkheads, an independent steam fire and bilge pump, and the ordinary bilge injections. The whole construction of the *Po-Yang* is highly creditable to the skill of Messrs. Roosevelt, Joyce & Co., and gives great satisfaction to her owners.

The Steamer J. W. Baldwin.—Hull built by M. S. Allen, New York. Machinery constructed by Fletcher, Harrison & Co., New York. Owners, Romer & Tremper, New York. Route of service, New York to Rondout.

Hull.—Length on deck, 242 ft. Breadth of beam, 34 ft. 3 ins. Depth of hold, 9 ft. Draft of water, 5 ft. 3 ins. Frames—molded, 16 ins.—sided, 5 ins.—apart at centres, 24 ins. Tonnage, 680 tons.

Engines.—Vertical beam. Diameter of cylinder, 60 ins. Length of stroke of piston, 11 ft.

Boilers.—Two—tubular—located on guards; have one blower to each, and no water-bottoms.

Paddle Wheels.—Diameter over boards, 30 ft. Material, iron.

Remarks.—This is an excellent vessel, and one well adapted to the wants of this much frequented route. Her frame is of white oak, chestnut, &c., and square fastened with copper and tree-nails.

The Steamer T. V. Arrowsmith.—Hull built by B. C. Terry, Keyport, N. J. Machinery constructed by Fletcher, Harrison & Co., New York. Owners, T. V. Arrowsmith & Co. Route of service, New York to Keyport.

Hull.—Length on deck, 200 ft. Breadth of beam, 27 ft. Depth of hold, 8 ft. 10 ins. Draft of water, 4 ft. Frames—molded, 13 ins.—sided, 6 ins.—apart at centres, 23 ins. Tonnage, 450 tons.

Engines.—Vertical beam. Diameter of cylinder, 44 ins. Length of stroke of piston, 10 ft.

Boilers.—One—flue—located in hold; uses a blower, and has no water-bottom.

Paddle Wheels.—Diameter over boards, 27 ft. Material, iron.

Remarks.—This vessel is constructed of white oak, chestnut, &c., and square fastened with copper and tree-nails. She is supplied with a steam pump, bilge injections, and the requisite fixtures essentially necessary for an excellent steamer.

The Steamer Key West.—Hull built by F. V. Tucker, New York. Machinery constructed by Daniel McLeod, Brooklyn, L. I. Owners, Hiram Benner & Co. Route of service, New York to New Orleans.

Hull.—Length on deck, 168 ft. 10 ins. Breadth of beam, 30 ft. Depth of hold, 11 ft. Do. to spar-deck, 18 ft. Draft of water, 10 ft. Frames—molded, 13 ins.—sided, 7 ins.—apart at centres, 24 ins. Rig, brigantine. Tonnage, 725 tons.

Engines.—Horizontal direct. Diameter of cylinders, 32 ins. Length of stroke of piston, 2 ft. 2 ins.

Boilers.—Two—tubular—located in hold, and do not use blowers.

Propeller.—Diameter, 10 ft. Pitch, 16 ft. Material, cast iron.

Remarks.—This vessel is of white oak, chestnut, &c., and is fastened with copper spikes and tree-nails. In her construction are combined strength, beauty of model, and speed. She is an excellent boat in every respect, and well worthy the excellent patronage she has received since she commenced to ply on this route.

The Steamer Mary A. Boardman.—Hull built by John Englis, New York. Machinery constructed by Neptune Iron Works, New York. Owners, Aymar & Co. In Government service.

Hull.—Length on deck, 160 ft. Breadth of beam, 27 ft. Depth of hold, 6 ft. Do. to spar-deck, 12 ft. Draft of water, 9 ft. Frames—molded, 13 ins.—sided, 6 and 7 ins.—apart at centres, 24 ins. Rig, schooner. Tonnage, 552 tons.

Engines.—Vertical direct. Diameter of cylinders, 26 ins. Length of stroke of piston, 2 ft. 2 ins.

Boilers.—One—return flue—located in hold, and uses a blower.

Propeller.—Diameter, 9 ft. Pitch, 17 ft. Material, cast iron.

Remarks.—This vessel is of white oak, chestnut, &c., and square fastened with iron and tree-nails. Around the frames iron straps, diagonal and double laid, $3\frac{1}{2}$ by $\frac{5}{8}$ inches, are placed, thus rendering them very secure. This steamer is calculated to do excellent service wherever employed.

The Steamer San Juan.—Hull built by Maxson, Fish & Co., Mystic, Conn. Machinery constructed by Morgan Iron Works, New York. Owners, M. O. Roberts & Co., New York. Route of service, Lake Nicaragua.

Hull.—Length on deck, 160 ft. Breadth of beam, 25 ft. 6 ins. Depth of hold, 8 ft. 6 ins. Draft of water, 4 ft. 5 ins. Frames—molded, 12 ins.—sided, 10 ins.—apart at centres, 22 ins. Tonnage, 335 tons.

Engines.—Vertical beam. Diameter of cylinder, 33 ins. Length of stroke of piston, 10 ft.

Boilers.—One—tubular—located in hold, and does not use blowers.

Water Wheels.—Diameter over boards, 26 ft. Material, wood and iron.

Remarks.—This is the first of some two or three new steamers designed by her owners to be employed in various ways upon their new route to California. She is an excellent vessel, and has so far as heard from, proved eminently successful. I trust her future career will be such as to prove pecuniarily remunerative to her owners. Her hull is of white oak, &c., and fastened in the securest manner.

The Steamer City of Norwich.—Hull built by John Englis, Greenpoint, L. I. Machinery constructed by Allaire Iron Works, New York. Owners, New York and Norwich Transportation Company. In Government service.

Hull.—Length on deck, 208 ft. Breadth of beam, 36 ft. Depth of hold, 12 ft. 6 ins. Draft of water, 5 ft. 3 ins. Frames—molded, 16 ins.—sided, 7 ins.—apart at centres, 25 ins. Tonnage, 890 tons.

Engines.—Vertical beam. Diameter of cylinder, 52 ins. Length of stroke of piston, 10 ft.

Boilers.—One—tubular—located in hold, and does not use blowers.

Water Wheels.—Diameter over boards, 31 ft. Material, wood and iron.

Remarks.—This steamer is of white oak, &c., and in the manner of her fastenings has iron straps running diagonally around the frames, and also fore and aft, thus rendering them very secure.

The Steamer Creole.—Hull built by Charles H. Mallory, Mystic, Conn. Machinery constructed by C. H. Delamater, New York. Owners, Ludlam, Heineken & Co., New York. Route of service, New York to New Orleans.

Hull.—Length on deck, 194 ft. Breadth of beam, 34 ft. Depth of hold, 18 ft. 7 ins. Do. to spar-deck, 25 ft. 6 ins. Draft of water, 14 ft. Frames—molded, 15 ins.—sided, 8 ins.—apart at centres, 26 ins. Tonnage, 1100 tons.

Engines.—Vertical direct. Diameter of cylinders, 36 ins. Length of stroke of piston, 3 ft.

Boilers.—One—return flue—located in hold, and uses a blower.

Propeller.—Diameter, 12 ft. Material, cast iron.

Remarks.—This vessel is of white oak, &c., and square fastened with copper and tree-nails. Around her frames—which are filled in solid—run iron straps, double and diagonal laid, 3 by $\frac{5}{8}$ inches, making them secure and staunch. The *Creole* has made the run to New Orleans and back several times, and has during these trips, given great satisfaction to all connected with her.

The Steamer Thomas Collyer.—Hull built by Thomas Collyer, New York. Machinery constructed by H. R. Dunham, New York. Owners, Alliance Machine Company. Route of service, New York to Port Monmouth.

Hull.—Length on deck, 205 ft. Breadth of beam, 27 ft. Depth of hold, 9 ft. Draft of water, 4 ft. 6 ins. Frames—molded, 14 ins.—sided, 8 ins.—apart at centres, 25 ins. Tonnage, 506 tons.

Engines.—Vertical beam. Diameter of cylinder, 48 ins. Length of stroke of piston, 10 ft.

Boilers.—One—tubular—located in hold, and uses a blower.

Water Wheels.—Diameter over boards, 27 ft. Material, wood.

Remarks.—This vessel is of white oak, chestnut, &c., and fastened with copper and tree-nails. She is furnished with an independent steam fire and bilge pump, and ordinary bilge injections. She is an excellent vessel for the route, and has given unqualified satisfaction during her period of service.

The Steamer Hu-Quang.—Hull built by Henry Steers, Greenpoint, L. I. Machinery constructed by Allaire Works, New York. Owners, J. M. Forbes & Co. Route of service, coast of China.

Hull.—Length of keel, 270 ft. Length on deck, 290 ft. Breadth of beam, 36 ft. 8 ins. Depth of hold, 14 ft. Do. to spar-deck, 20 ft. Draft of water, 8 ft. Frames—molded, 18 ins.—sided, 7 ins.—apart at centres, 24 ins. Rig, schooner. Tonnage, 1998 tons.

Engines.—Vertical beam. Diameter of cylinder, 76 ins. Length of stroke of piston, 12 ft. Is fitted with Sickles' cut off.

Boilers.—Two—return flue. Length, 30 ft. 3 ins. Breadth, 12 ft. 6 ins. Height, 11 ft. Located in hold, and does not use blowers.

Water Wheels.—Diameter over boards, 28 ft. Face, 12 ft. Material, iron.

Remarks.—This vessel is built of white oak, cedar, and hacmetac. Her model is one of much beauty, and her easy and graceful lines are such as to betoken great speed. She has iron straps, diagonal and double laid, running around her frames, securing them in the best possible manner, and making the vessel one of great strength. Her construction is another proof of the skill of American shipbuilders and American mechanics.

The Singapore (China) *Free Press*, of August 9th ult., referring to the trip of this vessel from New York to that port says: "The steamer *Hu-Quang* arrived here at 11, A. M., the 6th August, making the

quickest trip from America on record, being only 59 days 21 hours, exclusive of detentions for coaling, &c., at the intervening ports of St. Vincent, Simon's Bay and Mauritius. She made St. Vincent (Cape de Verdes) from New York, 28th May, at noon—distance 2897 knots—in 10 days 17 hours, and there remained 7 days 4 hours—leaving June 15, made Table Bay in 16½ days; lay-to 2 hours, and doubled the Cape of Good Hope, coming to anchor in Simon's Bay, after a run of 4 hours—the same day. At this place remained 8 days to coal, and left 10th July, at 2·30 P. M. Had rough weather on the African coast the following Saturday, and on Sunday in the Agullas current. Came to anchor in Port Louis, Mauritius, in 8½ days. Remained there 4 days, and left on 23d July, at 2 P. M.; encountered heavy seas during first 10 days out, and arrived from last mentioned port at Singapore, August 6, in 13 days 18 hours. Average speed, with 25 tons of coal per day, 12 knots. Best day's run on the passage, 325 knots; and least, 183 knots. On her trial trip, ran 17 statute miles in 53 minutes. Average speed from New York to this place, 11 knots."

The Steamer Clifton.—Hull built by J. Simonson, Greenpoint, L. I. Machinery constructed by Allaire Iron Works, New York. Owner, Cornelius Vanderbilt, New York. Route of service, New York to Staten Island.

Hull.—Length on deck, 185 ft. Breadth of beam, 34 ft. Depth of hold, 13 ft. 6 ins. Draft of water, 5 ft. 9 ins. Frames—molded, 15 ins.—sided, 7 ins.—apart at centres, 24 ins. Tonnage, 150 tons.

Engines.—Vertical beam. Diameter of cylinder, 36 ins. Length of stroke of piston, 8 ft.

Boilers.—One—return flue—located in hold, and does not use blowers.

Water Wheels.—Diameter over boards, 26 ft. Material, iron.

Remarks.—This vessel is constructed of white oak, &c., and is securely fastened in the most approved manner. She has an independent steam fire and bilge pump, and ordinary bilge injections.

The Steamer Trade Wind.—Hull built by T. T. Wetmore. Machinery constructed by J. M. Huntington & Co. Owners, J. M. Huntington & Co. Route of service, New York to New Orleans.

Hull.—Length on deck, 135 ft. Breadth of beam, 26 ft. Depth of hold, 13 ft. Do. to spar-deck, 18 ft. 6 ins. Draft of water, 9 ft. Frames—molded, 10 ins.—sided, 10 and 8 ins—apart at centres, 26 ins. Rig, three-masted schooner. Tonnage, 450 tons.

Engines.—Vertical direct. Diameter of cylinder, 36 ins. Length of stroke of piston, 2 ft. 6 ins.

Boilers.—One—flue—located in hold, and constructed of excellent material.

Propeller.—Diameter, 9 ft. Pitch, 18 ft. Material, cast iron.

Remarks.—This vessel is of white oak, chestnut, &c., and is square fastened with copper and tree-nails. She is admirably constructed, and well suited for the route now on, and the service engaged in, *i. e.* mail and passenger steamer.

The Steamer United States.—Hull built by C. & R. Poillon, Brook-

lyn, L. I. Machinery constructed by C. H. Delamater, New York. Owners, C. & R. Poillon. In Government service.

Hull.—Length on deck, 202 ft. Breadth of beam, 32 ft. Depth of hold, 12 ft. 3 ins. Do. to spar-deck, 19 ft. 3 ins. Draft of water, 12 ft. Frames—molded, 13 ins.—sided, 9 ins.— apart at centres, 24 ins. Rig, foretopsail schooner. Tonnage, 986 tons.

Engines.—Vertical direct. Diameter of cylinders, 36 ins. Length of stroke of piston, 3 ft.

Boilers.—One—flue—located in hold, and uses a blower.

Propeller.—Diameter, 13 ft. Pitch, 16 ft. Material, cast iron.

Remarks.—This vessel is of white oak, chestnut, locust, &c., and square fastened with copper and tree-nails. Iron straps, diagonal and double laid, 3½ by ⅝ inches, extend around them. Her model is without fault, and the short time she has been in service, has given the greatest satisfaction to all connected with her. Messrs. C. & R. Poillon may well feel proud of this excellent craft.

The Steamer Kiang-Tsze.—Hull built by Lawrence & Foulks, Williamsburgh, L. I. Machinery by Henry Esler & Co., Brooklyn, L. I. Owners, P. S. Forbes & Co. Route of service, coast of China.

Hull.—Length on deck, 200 ft. Breadth of beam, 33 ft. Depth of hold, 11 ft. 6 ins. Draft of water, 7 ft. 6 ins. Frames—molded, 15 ins.—sided, 6 ins.—apart at centres, 26 ins. Rig, foretopsail schooner. Tonnage, 1100 tons.

Engines.—Vertical beam. Diameter of cylinder, 50 ins. Length of stroke of piston, 11 ft.

Boilers.—Two—return flue—located in hold, and does not use blowers.

Water Wheels.—Diameter over boards, 28 ft. Material, wrought iron.

Remarks.—This steamer is constructed of white oak, chestnut, &c., and very securely fastened with copper tree-nails, &c. Iron straps, diagonal and double laid, 4 by ½ inches, extend around the frames. The *Kiang-Tsze*, on the route of her future service, will tend to permanently enlarge the already established reputation of American shipbuilders in the Chinese Empire.

The Steamer George C. Collins.—Hull built by George Goodspeed. Machinery constructed by Woodruff & Beach. Owners, New York and Hartford Steamboat Company. In Government service.

Hull.—Length on deck, 148 ft. Breadth of beam, 28 ft. Depth of hold, 7 ft. 6 ins. Draft of water, 6 ft. 6 ins. Frames—molded, 13 ins.—sided, 6 ins.—apart at centres, 24 ins. Rig, schooner. Tonnage, 300 tons.

Engines.—Vertical direct. Diameter of cylinder, 36 ins. Length of stroke of piston, 2 ft. 6 ins.

Boilers.—One—tubular—located in hold, and uses a blower.

Propeller.—Diameter, 8 ft. 4 ins. Pitch, 15 ft. Material, cast iron.

Remarks.—This vessel is of white oak, chestnut, &c., and put together in an excellent manner. Since she has been in the service of the Government she has done good service, and given excellent satisfaction.

The Steamers America and Union.—Hulls built by Webb & Bell, Greenpoint, L. I. Machinery constructed by Henry Esler & Co.,

Brooklyn, L. I. Owners, Union Ferry Company. Route of service, New York to Brooklyn.

Hulls.—Length on deck, 160 ft. Breadth of beam, 32 ft. Depth of hold, 12 ft. 6 ins. Draft of water, 6 ft. 6 ins. Frames—molded, 13 ins.—sided, 6 ins.—apart at centres, 23 ins. Tonnage, 509 tons.

Engines.—Inclined. Diameter of cylinder, 38 ins. Length of stroke of piston, 10 ft.

Boilers.—One—flue—located in hold, and does not use blowers.

Water Wheels.—Diameter over boards, 16 ft. Material, wood and iron.

Remarks.—These vessels are of white oak, &c., and fastened and rendered as secure and strong as practicable, their peculiar services demanding vessels capable of standing severe usage. I think their builders have been very successful in their construction.

The Steamer City of Hudson.—Hull built by T. C. Donaldson, New York. Machinery constructed by Fletcher, Harrison & Co., New York. Owners, Martin, Powers & Co., New York. Route of service, Catskill to Albany.

Hull.—Length on deck, 195 ft. Breadth of beam, 30 ft. Depth of hold, 7 ft. 9 ins. Draft of water, 4 ft. 3 ins. Frames—molded, 14 ins.—sided, 6 ins.—apart at centres, 24 ins. Tonnage, 512 tons.

Engines.—Vertical beam. Diameter of cylinder, 44 ins. Length of stroke of piston. 10 ft.

Boilers.—One—return flue—located in hold, and does not use blowers.

Water Wheels.—Diameter over boards, 26 ft. Material, wood.

Remarks.—This vessel is of white oak, &c., and is very securely fastened and strapped. She has excellent accommodations, and has given much satisfaction whilst in service on her present route. B.

New York, January 21, 1863.

(To be Continued.)

Changes in Iron.

From the London Builder, No. 1030.

At a recent meeting of the Manchester Literary and Philosophical Society, Mr. Dyer, Vice President, exhibited a broken screw bolt, $1\frac{1}{8}$ inch square (used to fasten a cart-body to the axle). The fracture, near the head end, appeared very much like one of cast iron: imbedded in the centre of the bar was a smooth egg-shaped mass about $\frac{1}{2}$-inch diameter, crossing the fracture, and leaving a cavity as its mould in the metal on one side. He assumed that faults like this were probably owing to the rapid processes in use for reducing masses from the puddle into bars of wrought iron, whilst the metal was only partially converted to the malleable state, as appeared in this sample of bad iron. The iron, in a semi-fluid state, is passed from the furnace through a succession of rollers, without re-heating or faggoting, as was formerly practised, and at once reduced to the sizes required. The improved rolling-mills could not, it seemed, insure improved qualities of wrought iron, whilst they afforded temptations to make it far infe-

rior to any that could have been made fifty years ago. Considering the many hazards to which life and property are exposed in traveling by railway and otherwise, from the iron "shuffled off in haste," and found in use in engineering constructions; it becomes important that previous tests should be employed to ascertain the real nature of the iron, so as to leave no question of its being in a safe condition for the purpose intended, and not like this specimen, and like much now-a-days made, by pressing the half converted puddle into marketable shapes.

In connexion with the subject of the slow changes which iron undergoes, M. Breguet, of Paris, stated that in their furnace for preparing soft iron, he had observed a remarkable case of crystallization of wrought iron. One of the furnace bars became brittle; and, on breaking a portion of it, he found it to contain a large cubical crystal of iron, each of whose sides measured five millimetres in length.

Wright's Tar-Paving.

From the London Mechanics' Magazine, December, 1862.

The many just complaints about the stone paving in the Inner Quadrangle of Somerset House, have at length been listened to. The whole of it has been taken up and the square covered with Wright's tar-paving, which is said to have been used with success at Woolwich and other Government works. The finishing layer of this material will not be put down until the spring of next year. It will then be fairly open to public criticism, and we shall take the opportunity of describing the process of its manufacture, its advantages, and the effect of weather and continual traffic upon it.

Iron Masts.

From the London Builder, No. 1038.

The following are the dimensions and weight of the masts sent to Pembroke from the Chepstow Ironworks, for the use of her Majesty's ship *Prince Consort*. The mainmast is 116 feet long by 37 inches in circumference, and weighs 18 tons 14 cwt.; the foremast is 110 feet long by 36 inches in circumference, and weighs 17 tons 10 cwt.; the mizenmast is 83 feet long by 24 inches in circumference, and weighs 5 tons 14 cwt.; the bowsprit is 43 feet long by 36 inches in circumference, and weighs 4 tons 10 cwt.

For the Journal of the Franklin Institute.

Strength of Cast Iron and Timber Pillars: A series of Tables showing the Breaking Weight of Cast Iron, Dantzic Oak, and Red Deal Pillars. By Wm. Bryson, Civ. Eng.

(Continued from Vol. xliv, p. 347.)

The pintles employed in the construction of the Pemberton Mill, in the lowest room, as O. B. M. says, "were 3 inches in diameter, 16$\frac{3}{4}$ inches from bottom to underside of flanch; flanch 7 inches in diameter, 1$\frac{1}{8}$ thick, supported by pillars 6 inches in diameter."

In a previous table—Vol. xliv., page 48—I have shown the calculated breaking weight of the pintle, proper, irregularly fixed to be 223 tons, one-fourth of which is 55 tons for the assumed safe weight.

The breaking weight of the flanch of the pintle, as given by Mr. Francis, he thought "would not be far from forty-five tons," that of O. B. M. "66,512 lbs." ÷ 2240 = 29·69 tons.

If the top bed of the flanch of the pintle had been turned off, or faced in the lathe, as it should have been, and the bottom of the pillar, six inches external diameter, and five-eighths of an inch thick, also turned so that the pillar would be accurately fitted to and firmly fixed on the top of the flanch, the pressure being uniformly distributed, then the breaking weight of the flanch of the pintle, if considered as a series of beams fixed at one end and loaded at the other, and that the ultimate pressure terminated at or on the line of the inner circumference of the pillar, seven-eighths of an inch from the neck of the pintle, and computed by either of the following formulæ, is 38 tons, or 28 tons if taken on the line of the mean circumference, and I have no doubt but that the flanch was capable of sustaining much greater pressure than I have obtained by calculation.

Formulæ for the strength of a rectangular beam fixed at one end and loaded at the other, Low Moor iron No. 3:

$$\left(^{1}\ w = \frac{f\,b\,d^2}{n\,\mathrm{L}}\right) \quad \left(^{2}\ w = \frac{526\,b\,d^2}{l}\right) \quad \left(^{3}\ w = \frac{4{\cdot}5\,b\,d^2\,467}{4\,\mathrm{L}}\right)$$

$$\left(^{4}\ \mathrm{W} = \frac{11{\cdot}258\,b\,d^2}{4\,\mathrm{L}}\right) \quad \left(^{5}\ \mathrm{W} = \frac{2{\cdot}8145\,b\,d^2}{\mathrm{L}}\right)$$

f = tensile strength per square inch = 14,535 pounds.

b = breadth in inches.

d = depth in inches.

n = 2·3.

L = length in inches.

l = length in feet.

w = breaking weight in pounds ÷ 2240 = tons.

W = breaking weight in tons.

But as the breaking weight of the flanch of the pintle can scarcely be viewed in this manner, it being a case depending on the tensile strength of the iron, which for Low Moor iron No. 3 is 14,535 pounds = 68·8 tons, and assuming that only one-third of the circumference of the pillar rested on the flanch, then the breaking weight is 68·8 ÷ 3 = 22·93 tons, and taking one-third of this it becomes 7·64 tons for the assumed safe weight, or taking one-sixth of the breaking weight for the whole flanch, it becomes 11·46 tons, or about equal to the assumed safe weight of the pillar.

From what information I have been able to obtain, it does not appear that any calculation for the strength of the pillars of the Pemberton Mill has been given in any of the evidence, but Capt. Bigelow stated that "The pillars were made tenfold stronger than required, according to sustain the weight which they held," and in his letter he says, "it is abundantly proved that the bad casting of the iron columns was the main cause of the disaster. Obtained from the source and in the manner they were, no calculation or allowance of strength would have been of any avail as security. These columns were calculated to bear only one-tenth of the breaking weight; and I apprehend that very few engineers in the world would say that a greater margin of security than this was needed." Mr. Francis stated, "about twenty-five tons on each of the lower columns," would be between one-ninth and one-tenth of the breaking weight, as calculated by Hodgkinson's rule, of the columns in the lower story."

O. B. M. says, "the largest pillars were in the first story or weave room, and measured 5 inches in diameter at the smallest part near the top, 12½ feet long, and their mean thickness ⅝ of an inch;" the pillars in the second story, he says, "I find them 4½ at the small end, with a mean thickness of ⅝ths of an inch, and 11½ feet long;" and again he says, "Since the disaster I have examined the thickness of several pillars in the mills at Lawrence, and find but little variation, the greatest not exceeding $\frac{3}{16}$ths of an inch." "But it seems if we would use iron to the best economy for strength, the pillars should be largest in the middle or at least straight."

I have no hesitation in saying that, even admitting the above dimension pillars to have been perfect castings, and that they were five-eighths of an inch thick, that from the manner of construction of the whole building they were totally inadequate for such a cotton factory as the Pemberton Mill, as the safe dead load should not on such pillars have exceeded 11·40 tons in the lower story, and 9·79 tons in the second story, by taking one-tenth of the calculated breaking weight for flat ends firmly fixed, or 12·45 tons in the former and 10·31 tons in the latter by taking one-fourth of the calculated breaking weight if irregularly fixed, and yet it has been shown that the estimated dead weight on the lower pillars was actually 25 tons; this, then, is only a trifle less than one-fourth of the calculated breaking weight, for a dead load, for the pillars in the lower story, even if they had been accurately fitted with flat ends and firmly fixed, and is not therefore either one-ninth or one-tenth of the breaking weight. I presume that the pillars in the lower story should not have been permanently loaded with more than 9 tons, and those in the second with more than 7½ tons.

Having already given so many calculations for the breaking weight of similar pillars as those employed in the Pemberton Mill, I will conclude the calculations on this subject by giving the following table, which is computed from Mr. Hodgkinson's formulæ for the strength of pillars, and shows the breaking weight and one-fourth and one-tenth of the

breaking weight calculated as hollow uniform cylindrical pillars with both ends flat and firmly fixed, for the smaller diameter, it being more critically correct than by taking the mean diameter; also the breaking weight and assumed safe weight of the same pillars with rounded ends or irregularly fixed, and for different thicknesses of metal.

The following formula is deduced from Mr. Hodgkinson's experiments on pillars of Low Moor iron No. 2, 10 feet long and from $2\frac{1}{2}$ to 4 inches diameter:

$$w = 46{\cdot}65\,\frac{D^{3{\cdot}55} - d^{3{\cdot}55}}{L^{1{\cdot}7}}$$

Hollow Uniform Cylindrical Pillars of Cast Iron, Both Ends being Flat and Firmly Fixed.

Length or height of Pillar in feet.	External diameter in inches.	Thickness of Metal. Inch.	Number of diameters contained in the length or height.	Calculated breaking weight in tons from formulæ $w = 46{\cdot}65\,\frac{D^{3{\cdot}55} - d^{3{\cdot}55}}{L^{1{\cdot}7}}$ $Y = \frac{w\,c}{w + \frac{3}{4}\,c}$	Assumed safe weight $\frac{1}{4}$ of the breaking weight. Tons.	One-tenth of the breaking weight in tons.
12·5	5·	$\frac{5}{8}$	30·	118·32	29·58	11·83
11·5	4·5	"	30·66	101·61	25·40	10 16
				$w = 44{\cdot}34\,\frac{D^{3{\cdot}55} - d^{3{\cdot}55}}{L^{1{\cdot}7}}$ $Y = \frac{w\,c}{w + \frac{3}{4}\,c}$		
12·5	5·	$\frac{5}{8}$	30.	114·05	28·51	11·40
11·5	4·5	"	30·66	97·90	24·47	9·79

Hollow Uniform Cylindrical Pillars of Cast Iron, Both Ends being Rounded or Irregularly Fixed.

				Calculated breaking weight in tons from formula $w = 13\,\frac{D^{3{\cdot}76} - d^{3{\cdot}76}}{L^{1{\cdot}7}}$		
12·5	5·	5-8	30·	49·83	12·45	
"	"	9-16	"	46·47	11·61	
"	"	1-2	"	42·81	10·70	
"	"	7-16	"	38·81	9·70	
"	"	3-8	"	34 47	8·61	
"	"	5-16	"	29·75	7·43	
"	"	1-4	"	24·65	6·16	
"	"	3-16	"	19·15	4·78	
"	"	1-8	"	13·22	3·30	
11·5	4·5	5-8	30·66	41·26	10·31	
"	"	9-16	"	38·63	9·65	
"	"	1-2	"	35·73	8 93	
"	"	7-16	"	32·52	8·13	
"	"	3-8	"	29·00	7·25	
"	"	5-16	"	25·14	6·28	
"	"	1-4	"	20·91	5·22	
"	"	3-16	"	16·31	4·07	
"	"	1·8	"	11·30	2·82	

"Three weeks after the accident, the following statement was made of the number of sufferers :

"Killed outright 83, since dead 3, total dead,	86
Badly injured, . . .	116
Injured, but not seriously, . .	159
Total killed and wounded, .	361"

What was the cause of all this suffering and what was the cause of the fall of the mill, the verdict, which I believe to be just, fair, and impartial, says "that the direct cause of the fall of this mill was the weakness and insufficiency of the cast iron shoring, &c."

I am inclined to the opinion that the cause was attributable not only to the weakness of the pillars and imperfection of the casting, but from the undue overloading, which was two to one or more for such pillars of the limit of safety for a dead load, and that the primary cause was produced or originated by the moving of the four fly frames, which it was thought by Samuel W. Jackson, "weighed 8500 pounds a piece" = 3·79 tons. I have no doubt but that some of the pillars were loaded with a live load equivalent to the dead load or calculated breaking weight of irregularly fixed pillars, or to about one-third of the calculated breaking weight of the same pillars, if firmly fixed, which is far from one-tenth of the breaking weight.

Cast iron being a crystalline material, brittle and uncertain, I am aware that all consistent allowance ought to be made in case of the failure of a body composed of it. Castings having all the appearance of soundness may contain imperfections not externally observable, and the permanent condition of well cast pillars is liable to be affected by the constant motion of the machinery and the operatives in a factory, and of course their condition will more rapidly be affected when badly cast and imperfectly set.

A poor casting, such as an imperfectly cast eccentric hollow cylindrical iron pillar subject to vibration, may be considered analogous to failing human nature, fragile, deficient, weak, overworked, overloaded beyond its strength, it may survive for one, two, three, aye even six years, and by receiving some sudden vibratory shock be broken down, sooner or later, but it would eventually occur as in the case of the cotton factory known as the Pemberton Mill.

Solid Uniform Square Pillars of Dantzic Oak, Both Ends being Flat and Firmly Fixed.

Length or height of Pillar in feet.	Side of the square in inches.	Number of diameters contained in the length or height.	Value of w in tons from formula. $w = 10{\cdot}95\,\frac{D^4}{L^2}$	Value of c.	Calculated breaking weight in tons from formula. $T = \frac{w\,c}{w + \frac{3}{4}c}$	Strength per square inch of section in tons.
6	10	7·2	3041·66	345·1	318·03	3·18
7	"	8·4	2234·69	"	309·27	3·09
8	"	9·6	1710·93	"	299·75	2·99
9	"	10·8	1351·85	"	289·64	2·89
10	"	12·	1095·00	"	279·12	2·79
11	"	13·2	904·95	"	268·35	2·68
12	"	14·4	760·41	"	257·46	2·57
13	"	15·6	647·92	"	246·59	2·46
14	"	16·8	558·67	"	235·84	2·35
15	"	18·	486·66	"	225·28	2·25
16	"	19·2	427·73	"	215·00	2·15
17	"	20·4	378·89	"	205·03	2·05
18	"	21·6	337·96	"	195·43	1·95
19	"	22·8	303·32	"	186·20	1·86
20	"	24·	273·75	"	177·38	1·77
21	"	25·2	248·29	"	168·96	1·68
22	"	26·4	226·23	"	160·95	1·60
23	"	27·6	206·79	"	153·35	1·53
24	"	28·8	190·10	"	146·13	1·46
25	"	30·	175·20	"	139·30	1·39
26	"	31·2	161·98	"	132·84	1·32
27	"	32·4	150.20	"	126·72	1·26
28	"	33·6	139·66	"	120·95	1·20
29	"	34·8	130·20	"	115·50	1·15
30	"	36·	121·66	"	110·34	1·10
Solid Uniform Square Pillars of Red Deal, Both Ends being Flat and Firmly Fixed.						
			$w = 7{\cdot}81\frac{D^4}{L^2}$			
8	10	9·6	1220·31	294·	249·00	2·49
9	"	10·8	964·19	"	239·27	2·39
10	"	12·	781·00	"	229·27	2·29
11	"	13·2	645·45	"	219·13	2·19
12	"	14·4	542·36	"	209·02	2·09
13	"	15·6	462·13	"	199·03	1·99
14	"	16·8	398·46	"	189·26	1·89
15	"	18·8	347·11	"	179·78	1·79
16	"	19·2	305·07	"	170·65	1·70
17	"	20·4	270·24	"	161·89	1·61
18	"	21·6	241·04	"	153·54	1·53
19	"	22·8	216·34	"	145·60	1·45
20	"	24·	195·25	"	138·07	1·38
21	"	25·2	177·09	"	130·95	1·30
22	"	26·4	161·36	"	124·23	1·24
23	"	27·6	147·63	"	117·90	1·17
24	"	28·8	135·59	"	111·94	1·11
25	"	30·	124·96	"	106·34	1·06
26	"	31·2	115·53	"	101·07	1·01
27	"	32·4	107·18	"	96·13	0·96
28	"	33·6	99·61	"	91·48	0·91
29	"	34·8	92·86	"	87·12	0·87
30	"	36·	86·77	"	83·02	0·83

Solid Uniform Cylindrical Pillars of Dantzic Oak, Both Ends being Flat and Firmly Fixed.

Length or height of Pillar in feet.	Diameter in inches.	Number of diameters contained in the length or height.	Value of w in tons from formula. $w = 6{\cdot}71\ \frac{D^4}{L^2}$	Value of c.	Calculated breaking weight in tons from formula. $Y = \frac{w\,c}{w + \frac{3}{4}c}$	Strength per sq. inch of section in tons.
8	10	9·6	1048·43	271·04	227·02	2·89
9	"	10·8	828·39	"	217·60	2·77
10	"	12·	671·00	"	208·02	2·64
11	"	13·2	554·54	"	198·33	2·52
12	"	14·4	465·97	"	188·71	2·40
13	"	15·6	397·04	"	179·26	2·28
14	"	16·8	342 34	"	170·05	2·16
15	"	18·	298·22	"	161·17	2·05
16	"	19·2	262·10	"	152·64	1·94
17	"	20·4	232·17	"	144·51	1·83
18	"	21·6	207·09	"	136·77	1·74
19	"	22·8	185·87	"	129·45	1·64
20	"	24·	167·75	"	122·54	1·56
21	"	25·2	152·15	"	116 02	1·47
22	"	26·4	138·63	"	109·89	1·39
23	"	27·6	126·84	"	104·14	1·32
24	"	28·8	116·49	"	98·73	1·25
25	"	30·	107·36	"	93·67	1·19
26	"	31·2	99·26	"	88·92	1·13
27	"	32·4	92·04	"	84·47	1·07
28	"	33·6	85·58	"	80·30	1·02
29	"	34·8	79·78	"	76·39	0·97
30	"	36·	74·55	"	72·72	0·92
Solid Uniform Cylindrical Pillars of Red Deal, Both Ends being Flat and Firmly Fixed.						
			$w = 4{\cdot}79\ \frac{D^4}{L^2}$			
6	10	7·2	1330·55	230·9	204·30	2·60
7	"	8·4	977 55	"	196·15	2·49
8	"	9·6	748·43	"	187·51	2·38
9	"	10·8	591·35	"	178·59	2·27
10	"	12·	479·00	"	169·58	2·15
11	"	13·2	395·86	"	160·63	2·04
12	"	14·4	332·63	"	151·84	1 93
13	"	15·6	283·43	"	143·32	1·82
14	"	16·8	244·38	"	135·13	1·72
15	"	18·	212·88	"	127·32	1·62
16	"	19·2	187·10	"	119·91	1·52
17	"	20·4	165·74	"	112·91	1·43
18	"	21·6	147·33	"	106·33	1·35
19	"	22·8	132 68	"	100·16	1·27
20	"	24·	119·75	"	94·39	1·20
21	"	25·2	108·61	"	88·99	1·13
22	"	26·4	98·96	"	83·96	1·06
23	"	27·6	90·54	"	79·27	1·00
24	"	28·8	83·15	"	74 90	0·95
25	"	30·	76·64	"	70·83	0·90
26	"	31·2	70·85	"	67·04	0·85
27	"	32·4	65·79	"	63·50	0.80
28	"	33·6	61·09	"	60·21	0·76
			Calculated breaking weight from the above formula.			
29	"	34·8	56·95	"	. .	0·72
30	"	36·	53·22	"	. .	0·67

For the Journal of the Franklin Institute.

On Iron-clad Ships, with Plans and Specifications of an armored Corvette proposed for the United States Government. By JOHN W. NYSTROM, C. E.

Armored ships are yet experiments, and a subject now of considerable importance in this country. It is a rather difficult undertaking to combine all requirements of an iron-clad man-of-war, particularly for one of small size and for shallow water. The most important requirements are,—*impregnability, speed, superior ordnance, good sea-going and sailing qualities,* comfort on *board, simplicity and no complicated machinery,* and *lateral strength of the hull of the ship,* all of which are to a certain extent combined in the corvette about to be described.

In August, 1861, and February, 1862, the Navy Department at Washington invited the ingenuity of the country to make proposals for the construction and building of iron-clad steamers, which was at both times promptly responded to by a great many plans, of which the corvette herein described is one of the two submitted by the writer.

The two sizes of armored steamers which I proposed to build were constructed to accommodate the stipulations in the Navy Department's advertisement. It is, however, believed that smaller boats would answer better for the present requirement peculiar to the country, but in all cases small gun-boats are best suited for home service; a greater number could be built in a shorter time, which would be more effective in blockading the long American coast. Armored gun-boats of 125 feet long, 20 feet wide, with only 7 feet draft of water, mounting one or two heavy guns, could go by inland navigation from New York to Fortress Monroe; they could even be made to draw 10 feet water by taking in coal and ordnance after arriving in sufficiently deep water. The object of which would be to surprise or attack an enemy's fleet at Sandy Hook, Delaware Bay, or in the Chesapeake. If the Navy Department would allow themselves to part from the Erie experiment principle and employ our present knowledge in steam engineering, gun-boats of this size could easily be made to carry fuel for six days steaming. A number of small gun-boats are not so easily surprised, and if a blunder is made in one or more of them the risk is not so great as in a line-of-battle. They are, however, easier managed, and if damaged they can go behind islands and shoals out of the reach of the enemy's fire. An experimental gun-boat of this size could be built in two months, and if proved successful almost any number could be built in the next two or three months.

Armored ships must yet be considered an experiment, for which a number of large ones bears a greater risk in expense and blunders. The large size armored steamers built in European navies are intended more for service abroad, for which they are well suited and less expensive than a number of small ones, but our case is of a different nature.

In the Russian war with England and France, an English naval officer proposed a plan by which to attack and bombard Cronstadt

with a number of small gun-boats, which was considered the most safe and effective, but peace was restored and the plan abandoned.

A corvette on the plan about to be described will be as *impregnable* as any iron-clad now building in Europe. As regards *speed*, the conditions set forth in the Navy advertisement were such that speed could not possibly be attained, for the greatest speed I can with safety guarantee is 10 knots, but am able to construct an iron-clad of the same or smaller size with 15 knots per hour. Although speed is of great importance, there are no men-of-war in the U. S. Navy with good speed, and some of the iron-clads lately built, can hardly walk by themselves, but must have a tow-boat to help them along; also the gun-boats built on the Erie experiment principle can only walk.

The sea-going and sailing qualities of the corvette will be as good as that of any merchant vessel of the same proportions; it is in every respect a ship-shaped vessel. A man-of-war may come in battle once or twice, or say a dozen times in a lifetime; it would be improper to sacrifice *comfort*, *health*, and *life* for some temporary importance; in the corvette proper attention is paid to comfort of officers and men on board by a house placed between the cupolas on the main deck. This house does not interfere with the proper management of a battle,—should it be injured by the enemy, *repair it*,—should it be shot away entirely, *build a new one*.

The *lateral strength* of an armored ship for shallow water, requires the greatest consideration both in design and workmanship; wooden vessels can hardly be made strong enough for that purpose. An iron-clad now building at the Philadelphia Navy Yard will hardly have lateral strength enough for the waves inside the Delaware breakwater.

Specification of an armored corvette with six 11*-inch guns.*—Figure 1, Plate III, represents the outer appearance of the corvette, with two armor cupolas on deck, in each of which are to be placed three 11-inch guns.

Figure 2 is a longitudinal section, showing the internal arrangement, and fig. 3 a plan of the boat; the arrows show the limit of angle in which the guns can be trained in each port-hole.

Figure 4 is a transverse section through the line AB, figs. 2 and 3, showing the armor guards and cupola with one gun. The armor guards above the water-line are at an angle of 45° and of 5 inches thick iron plates; under the water-line the guards are at an angle of 67½°, and of 3 inches thick iron plates.

Figure 5 is a plan of the cupola, showing the three guns, of which it is proposed to use two at a time, and have one for reserve in case the others should get injured or hot during the firing. With some practice it might be possible to employ the three guns at the same time, depending on the enemy's position.

DIMENSIONS OF THE BOAT.

Length on the water-line,	225 feet.
Breadth of beam moulded,	40 "
Extreme breadth over guards,	45 "
Draft of water,	12 "
Greatest immersed cross section,	436 square feet.

Greatest cross section including guards,	450 square feet.
Displacement,	2125 tons.
Speed in miles per hour,	10 knots.
Horse power of engines,	900 horses.

The corvette to be made wholly of iron, with two propellers, and schooner rigged.

Description of Iron Work.—Keel.—The centre keel to be of plate iron 1¼ inches thick, by about 2 feet wide, bent to suit the form of the boat; also two keels of solid rolled beam iron 12 inches deep, one on each side, as shown in fig. 4.

Sternpost to be of wrought iron in one piece, with a stuffing-box and heel for the rudder, as shown in fig. 2.

Sternpost to be made in one piece from deck to keel, as shown in fig. 2.

Plating.—The hull to be of ¾-inch plate iron, lapped longitudinally and butt-jointed vertically, the butts to be double riveted in each plate. The streaks to be about 3 feet wide from centre to centre of rivets, except in the stern and bow, where it diminishes according to the ordinary mode of iron shipbuilding. All the seams to be caulked, in and outside. The ¾-inch iron plating to extend in about 150 feet under the guards, the balance at the stern and bow to be plated with 4 inches thick iron plates above the water-line; from the water-line to 6 feet depth, to be plated with three inches plates; from 6 feet under water-line the keel to be plated with ¾-inch iron, except in the bow, where one streak from 6 to about 9 feet depth to be 2 inches, and from 9 to about 12 feet depth to be 1 inch thick. The butt pieces in the armor streaks to be 1½ inches thick, screwed on with 1½ inches tap screws, 2½ inches into the 4 inch armor plates; under the water-line the butt pieces are to be riveted.

Ram.—The ram of the corvette is to be formed by the armor-plates, terminating in the form of the stem, as shown in fig. 2. The object of making the ram in this round shape, is to distribute evenly on the vessel the shock of a collision; also for preventing the ram sticking fast in the vessel run into. The rams now made for some vessels in the Navy, with a small piece of iron sticking out from the stem, is a rather unsafe contrivance; should it stick fast for only one minute, the enemy's vessel will likely be hung upon it, which may give time enough for the enemy to board us, and should the enemy's vessel have a velocity forward while attempting to run into it, the ram may be broken off and injure our vessel more than the enemy. The *Merrimac's* ram was broken while running into our vessels in Hampton Roads.

Frames.—The frames to be spaced 18 inches apart; every other of beam iron, solid rolled 12 inches deep, and every other of beam iron ¾ (6+4) inches. The frames to be in as long pieces as possible with broken joints. In the most curved parts of the stern and bow where it is not possible to bevel the beam iron, the frames to be made of ¾ (6+4) inches angle iron; also the frames on the bulkheads to be of the same iron.

Beams.—The beams to be of beam iron, solid rolled, 12 inches deep, spaced 3 feet apart, one on every other frame, bent at the gunwales in continuation of the frames, as shown in fig. 4. The joints of the frames and beams to be riveted with butt pieces $\frac{5}{8}$-inch thick by 3 feet long, one on each side, with one inch rivets. The beams over the bulkheads to be of angle iron $\frac{3}{4}$ (6 + 4) inches. Under deck beams to be 6 inches solid rolled beam iron, riveted to the frames as shown in fig. 4. Under each cupola to be 6 intermediate beams of 9 inches solid rolled beam iron, as shown in the section fig. 2.

Stringers.—The gunwale stringer to be of plate iron 1 (12+12) inches, firmly riveted to the iron deck and side of the vessel, as shown in fig. 4. The stringers to circumscribe the entire vessel.

Keelsons.—To have three keelsons, the centre one to be of solid rolled beam iron 12 inches, and one on each side of 9 inches, spaced 9 feet 6 inches apart, as shown in fig. 4. The keelsons to be firmly riveted to each frame.

Longitudinal Beams to be of 9 inches solid rolled beam iron, spaced 9 feet 6 inches apart, and firmly riveted to the deck beams.

Bulkheads.—To have five water-tight bulkheads of $\frac{1}{2}$-inch iron diagonaled on both sides with angle iron $\frac{1}{2}$ (3 + 2) inches, as shown in fig. 4.

Decks.—To have two decks, the upper one to be of $1\frac{1}{2}$ inches thick plate iron next to the beams, butt-jointed in all seams with $\frac{3}{4}$-inch butt pieces; the longitudinal seams to run in one line, and broken cross seams. The iron deck to be covered with 8 inches thick planks, screwed fast from underneath. The under deck to be of $\frac{1}{2}$-inch iron with longitudinal lap seams and butt-jointed cross-seams, covered with 4 inch thick plank, screwed fast from underneath.

Rudder.—To have a balance rudder of wrought iron, fitted so as to be protected from enemy's shots. The rudder to be worked either in the pilot house on deck, or under deck in the mariners' room abaft. I have made this kind of rudder on several steamers in Russia, and found it to answer exceedingly well: it has many advantages above the single rudder,—it is easier managed, the vessels steer better with it, and it is less affected by the sea,—fig. 2 shows how it is arranged.

Armor Cupolas.—To have two armor cupolas on the main deck, of a spherical form, 25 feet diameter at the base and 10 feet high. The armor plates to be 6 inches thick, jointed in 12 segments with 8 inches solid rolled beam iron, as shown by fig. 6. Each cupola to have six port holes, in which the guns can be trained in a horizontal angle of 90°, and vertically about 47°. The port holes to be 3 feet wide by 4 feet high, covered with a sliding shutter $4\frac{1}{2}$ inches thick, as shown by figs. 4 and 5. The shutters to be worked from the inside. Each cupola to admit firing in a horizontal angle of 330°. The tops of the cupolas to have a hatchway 6 feet in diameter, covered with a plate $4\frac{1}{2}$ inches thick, which latter to have a hole 2 feet in diameter, covered with an iron grating. Cupolas of this description are considered strong enough without any backing of wood, which latter would greatly interfere with the proper training of the guns. The spherical form ren-

ders them as strong as 9 inches thick flat iron, and exposes the least possible surface to the enemy.

Armor Guards.—The armor guards to extend about 185 feet on each side of the boat; the armor plates to be 5 inches thick, placed on wood at an angle of 45° from the water-line to the bulwark, as shown in fig. 4. The plates to be fastened with tap bolts from the gunwale stringer, and with screw bolts at the lower edge or water-line, through the wood to the hull of the boat. The armor plates will be 6 feet 6 inches wide, and in as long pieces as possible, but not less than 10 feet. The lower armor plates to be 3 inches thick, by 5 feet wide, placed at an angle of 67½°. The wood backing to be of the hardest dry oak. The ends of the armor plates to be butt-jointed, but not riveted; under each cross-joint of the 5 inch plates to be laid a butt piece 2 inches thick by 9 inches wide, fitted into the wood, and under the 3 inch plates a similar butt piece 1½ inches thick. The guards to extend on each side to where the armor plates of the stern and bow commence, so that nothing of the ¾-inch plating will be exposed.

An armor plate placed at an angle, increases in horizontal thickness as the *secant* of the angle of inclination to the vertical plan. On this principle English engineers argue that a vertical plate of the same horizontal thickness as the inclined one has the same strength; which theory will hold good as regards lateral strength,—but it is the reflecting power which is taken advantage of in the inclined plate. The reflecting power is in proportion as the *tangent* of the angle of inclination; that the *secant* and the *tangent* added together, and the sum multiplied by the true thickness of the inclined plate, will give the relative value to the vertical one. The lateral strength of an armor plate is in proportion as the square of the thickness when the breaking force acts slowly,—but in the sudden shock of a projectile, the inertia of the armor plate acts as a die in a punching machine, where the resistance of the plate is in proportion direct as the thickness.

Deck Fittings.—*Bulwark* to be of wood boarded with 3 inches plank, intended to be made fast and not to be saved in a battle, but should it be desired to make it removable it can easily be made so.

Capstans.—To have two capstans, one forward and the other abaft, arranged so that each can be worked by any number of men from 1 to 16, without change of gearing or other complicated machinery; also to be made so as to pinch hold of any size of chain or hemp cable.

Deck Lights.—To have deck lights to the officers' and mariners' rooms, as shown in the plan, fig. 3,—with frames ground water-tight in the deck, and arranged so as to be easily opened for ventilation under deck; also to be provided with stand pipes of about 2 feet high above deck, for ventilation in rainy or stormy weather.

Davits.—To have two anchor davits in the bow, and eight boat davits, two for each boat, as shown in figs. 2 and 3.

House on Deck.—To have a house on deck of an elliptical form, as shown by the strong dotted lines fig. 3; length 85 feet by 20 feet wide,

to be made wholly of iron about $\frac{1}{4}$-inch thick. The window shutters to be made of $\frac{1}{2}$-inch iron, perforated with rifle holes. The roof beams of the house to be made of angle iron $\frac{3}{8}$ ($2\frac{1}{2}+3$) inches, covered with iron plates $\frac{1}{8}$-inch thick, on the top of which to be wooden boards $1\frac{1}{2}$ inches thick. The house to contain two kitchens, dining room for officers, cabin, &c., and arranged to suit the requirement. The top of the house to be circumscribed by a brass railing. To have two iron stairways, one forward and one abaft of the cupolas. The house is not intended to be saved in time of battle; if a ball should strike it there will only be a hole. All the furniture in it to be made of iron or other incombustible materials, that it cannot take fire.

Water Closets.—To have two water closets on the fore deck, mounted on hinges, so that they can be felled down when it is required to fire forward. Also water closets under deck with pumps.

Pilot House.—To have a pilot house made wholly of iron, located as shown in figs. 1, 2, and 3. During a battle the helmsman is stationed in the mariners' room abaft, and is directed by a dial worked from either of the cupolas.

Rigging.—To be three-masted schooner-rigged, as shown by fig. 1. All standing rigging to be of wire rope. It is schooner-rigged for the sake of making it simple, and the least possible number of ropes.

Life Boats.—To have four life boats of the most approved form, complete, with oars.

Hatchways.—To have nine hatchways, covered with spherical armor plates as shown in fig. 2. The two hatchways in each cupola to be covered with flat plates level with the floor. The combings to be of iron, riveted to the iron deck and projecting one foot above the wooden deck.

Figure-head and Bowsprit are arranged so that they can be removed in one minute, when the stem is a ram for running into an enemy's vessel.

Accommodation.—Under main deck is a space of 114 feet in length, occupying the whole width of the boat, of which 48 feet is abaft and 66 feet forward; also a forecastle of 30 feet to the stem; all to be arranged in the most suitable manner for officers, mariners, and crew. The water tanks are placed under the lower deck, as shown on the drawing, fig. 2, arranged with pumps, cocks, and pipes, as may be required.

Machinery.—The machinery, to consist of two horizontal condensing engines, working separately, each on a propeller shaft, as shown on the drawing figs. 2 and 3; to be of the most simple construction and most efficient in its performance, arranged with expansion, superheating of steam, and fresh water condenser, all up with the present knowledge of steam engines.

DIMENSIONS OF ENGINES.

Diameter of cylinders,	42 inches.
Stroke of piston,	30 "
Pressure of steam,	50 lbs.
Expansion $\frac{3}{4}$ to $\frac{1}{4}$.	
Actual horse power engines,	900 horses
Propellers, diameter,	10 feet.

Steam Boilers.—To have three cylindrical boilers of the most simple construction; every part of the inside to be accessible for cleaning.

Outside diameter 9 feet by 15 feet long.

Area of fire-grate,	96 square feet.
Fire surface,	2880 " "
Consumption of fuel per hour,	2450 lbs.
Consumption of fuel per day of 24 hours,	26·3 tons.
Consumption of fuel per seven days,	160 "

Ventilators.—To have two ventilators (fans) in the engine room, each 42 ins. diameter by 15 ins. wide. Air pipes to lead under the fire-grates, between decks and cupolas, as may be required for ventilating the ship.

Donkey.—To have one donkey engine with double-acting pump, arranged with cocks and pipes, so as to be used for feeding the boilers, bilge-pump, and fire engine.

Propellers.—To have two brass propellers 10 feet in diameter, each with four blades, arranged on the shafts so as to be easily shipped or unshipped as may be required at sea.

Coal-bunkers.—To have coal bunkers divided into two water-tight compartments, with capacity for 100 tons of coal.

Ordnance.—The ordnance to consist of six 11-inch guns, three in each cupola, mounted on carriages made wholly of wrought iron. The gun carriages to be mounted each on three wheels on vertical spindles turned in the direction the gun is desired to be moved. The two wheels under the gun to be turned by a worm screw, and the hind wheel by a lever; the course of the gun to be steered by the lever both in the recoil and when moving it. The floor in the cupolas to be made of iron and perfectly flat, that the guns can be hauled on it in any direction. When the gun is to be fired, the two wheels are turned crosswise with the screw, the recoil is then taken partly by the friction of those wheels on the floor, and the balance by a friction wheel around which is a chain or hemp cable fastened with one end in the cupola. By this arrangement the guns can easily be trained in a horizontal angle of 90° in each port-hole. The axis of the guns will be only 7 feet above the water-line, for which it would rarely be required to dip it under the horizon, but should it be required to fire in the direction *ab* fig. 4, the enemy must be very near, when the bulwark is of little importance; fire it away, and the projectile will strike the water at a distance of 19 yards. The guns can be elevated to an angle of 35°. At the circumference in the cupola are six holes *d*, *d*, of about 14 inches diameter, for handing up ammunition during firing. If more complicated gun carriages are adopted, it will necessarily throw out one of the three guns in each cupola.

Under the cupolas are steam hoisting machines H, fig. 4, composed simply of a cylinder 12 inches diameter by 15 feet stroke, to be used for hauling the guns, which dispenses with a great number of men and confusion in the cupolas. With 50 lbs. of steam, the machine can pull $2\frac{1}{2}$ tons.

The principal armor plates in the vessel herein described are independent of the hull of the same. Should it at any time be desired

to dispense with the heavy armor, it can easily be removed and there remains a comfortable and well proportioned steamer. It is practically demonstrated by the *Warrior* that it is not good to make the principal armor plates constitute the hull of the vessel, for the difficulty of keeping it tight after having worked in heavy sea. It is also believed that it is not practical to combine iron and wood in the hull of an armored vessel, particularly for shallow draft, but even the size of *La Gloire* has proved a failure in that respect, and the objection will become more serious for lighter draft. A vessel can be considered a long girder, of which the strength is in proportion as the square of the depth. Neither is it practicable to make water-tight bulkheads and iron decks in a wooden vessel, for one material will tear the other to pieces in a heavy sea.

It may be remarked that the anchors and propellers are not protected by a bill and tail as in the Monitors; to which I beg to reply that if the tail really protected the propeller, and if it could be made so as not to injure the speed and sea-going quality, and not endanger the safety of the ship, it would be proper to put such a thing on; but, as long as that is doubtful, it is preferable to avoid the trap, in consideration that it is better to lose both the propellers in a battle, than to have the vessel foundered at sea, before it reaches the enemy. It is of equal importance to get safe into a battle as to get safe out of it—both the purposes should be equalized and not neglected. The temporary importance of the bill and tail makes the vessel more unsafe out of battle than in the battle. The chance of a propeller being hit in the water is very rare: at any rate, it would be better to make the propellers of cast iron, and with at least four blades each, so that if it should be struck by a projectile, one blade may break off without further injury to the shaft or the stern-bearing. Two propellers would have eight blades, and suppose that even seven of them were shot away, still the steamer would make a good speed with the one blade left. If a blade of a brass propeller is struck, its strength does more harm to the shaft and stern of the vessel than if broken off; and it may bend so as to prevent the propeller from turning in its determined space.

An armored steamer as herein described will cost 850,000 dollars, complete for sea, but without ordnance and ammunition. On account of preparations necessary for the heavy armor plates, which in the cupola will weigh about 6½ tons each, it will require 12 months to complete one such steamer. It can be built on my own shipwharf, and the machinery, boilers, and armor plates manufactured in my own establishment located at Gloucester City, N. J., opposite Philadelphia.

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*Mr. Nasmyth's Improved Form of Link Motion.**

From the Practical Mechanic's Journal, Dec. 1862.

In many important applications of the Steam Engine, it is essential that we should possess the means of reversing at pleasure the direction of the revolution of the crank shaft.

* The above is the substance of a communication made by James Nasmyth to Section G, at the recent meeting of the British Association at Cambridge, Oct. 2, 1862.

Prominent instances of the desirableness of this capability are presented in the case of the locomotive and in the marine engine, as also in the case of "winding engines," as employed in colliery and other mining purposes.

Many contrivances have been resorted to for the attainment of the object in question, all of which, however, have been characterized by considerable complexity, and consequent liability to derangement, unfaithfulness of action, as well as rapid wear and tear.

It was not until the invention and introduction of the justly celebrated "link motion," that the problem of how to reverse the motion of a steam engine received its *perfect* solution, at the hands of a mechanic in the service of Robert Stephenson & Co., of Newcastle-upon-Tyne, who in the invention of the link motion, added one of the most beautiful and perfect details to the steam engine, and has thereby conferred a vast benefit on mankind. Not only does the "link motion," solve the problem of "how to reverse the action of the steam engine;" but also by its means we obtain at the same time a variable expansive valve motion, combined with a means of arresting in the most gentle, yet effective manner, the motion of the steam engine, and in these respects combines in one beautifully simple whole, the properties of reversing gear, expansive valve gear, and throttle valve, all in one.

So perfect in all these respects is the action of the link motion, that the form first given to it by its inventors has been universally accepted, and became traditionary, in so far at all events as regards the loop or link form of its main and distinguishing feature is concerned. In the application of this beautiful invention to marine engines of the largest class, some disadvantages latent in the *loop* or link power begin to manifest themselves: the chief of which is the constructive difficulty of taking up the slack naturally due to the wear and tear of the swivel block, working inside the loop of the link, and the consequent unpleasant knocking action and increased wear which naturally accompanies any such undue slackness in the moving parts. Besides which, in order to give the requisite amount of rigidity to the large size of link employed in engines of the most powerful class, an amount of material has to be introduced which is in every respect desirable to avoid.

It was with the view to remove these objections, as well as to simplify and economize the cost of construction of such link motions, that Mr. Nasmyth contrived in 1852 what he terms his "*solid bar*" form of the link motion, and which he in the same year first introduced into actual machinery in a colliery winding engine which he made for a firm in South Yorkshire.

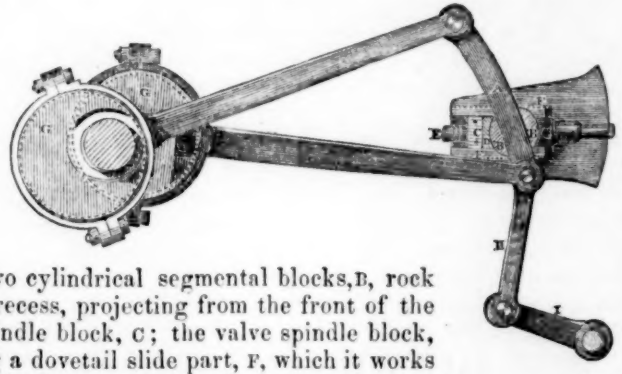
The perfect action in practice which was found to attend this simple "solid bar" form of the link motion, led his friend Mr. Edward Humphrys to introduce this solid bar link motion into his marine engines, in doing which, Mr. Humphrys has displayed his usual high skill and judgment, in the admirable manner in which he has adapted Mr. Nasmyth's invention, as may be seen in those magnificent marine engines

of 400 horse power, which Mr. Humphry's firm has sent to the great Exhibition of 1862.

As it is presumed that this subject can only interest those practically conversant with the details of steam engines, it will not be requisite to enter into any detailed description of "the link motion," as such, but simply to point out the nature of the modifications of form which specially characterize Mr. Nasmyth's arrangement of it—the main feature of which consists in the substitution of a solid bar, A, in the accompanying engravings, in place of the usual link or loop form of the part in question.

This solid bar, A, is coupled with the sliding block, C, to which the valve rod is attached, by means of two cylindrical segmental rocking blocks, B, between which the bar, A, slides, where one or other of the eccentrics is caused to convey its chief action to the valve.

The substitution of the simple solid bar, *a*, for the open link or loop hitherto employed, is not only more rigid and exact in its action, as well as economical in its construction and material, but by means of the setting up pad piece, *d*, and its set screw, E, all "slack" due to wear and tear can be removed, and the most perfect yet easy fit secured.



The two cylindrical segmental blocks, B, rock inside a recess, projecting from the front of the valve spindle block, C; the valve spindle block, C, having a dovetail slide part, F, which it works on, and which may be secured to or made part and parcel of the frame of the engine, and so secure most perfect exact action to the motion of the valve block, C, and its attached valve rod.

The lever, I, and connecting bar, H, are the means whereby the one or other eccentric, is made to convey its chief action to the valve in the usual manner.

A cover plate attached to the slide block, C, by four small bolts, the holes for which are indicated, keeps the slide or link bar, A, and the rocking segments, B, in their respective positions, and renders them easily accessible when need be.

Fig 1

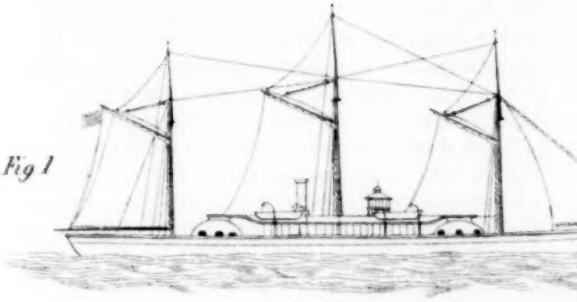


Fig 2

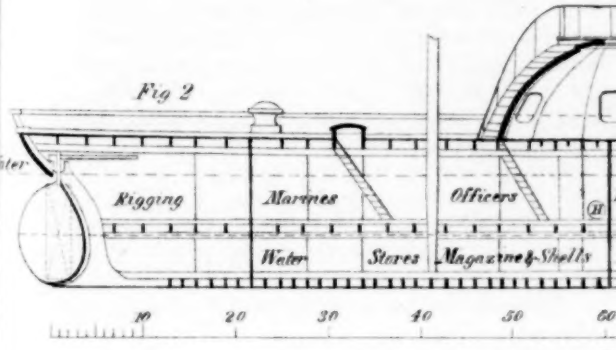
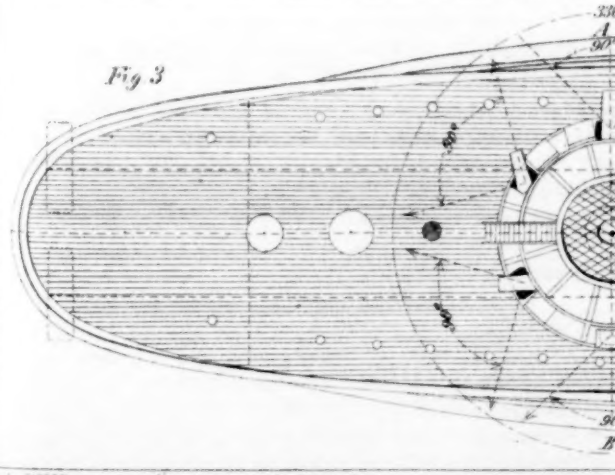


Fig 3



...by W.H.Rease, Cor. 4th & Chesnut St. Philad.

AN ARMORED CORVETTE WITH SIX GUNS

Proposed by John W. Nystrom C.E.

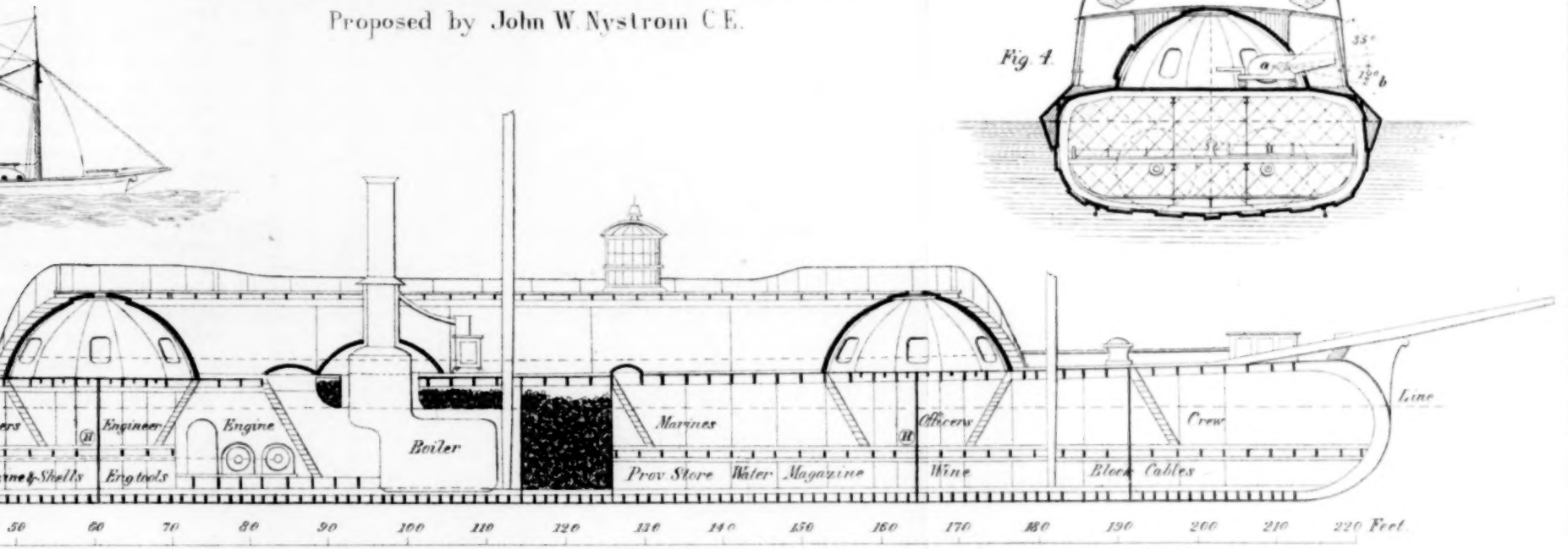
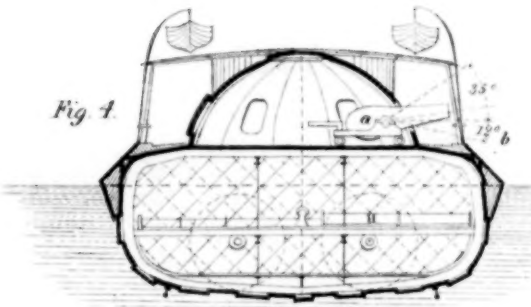


Fig. 4



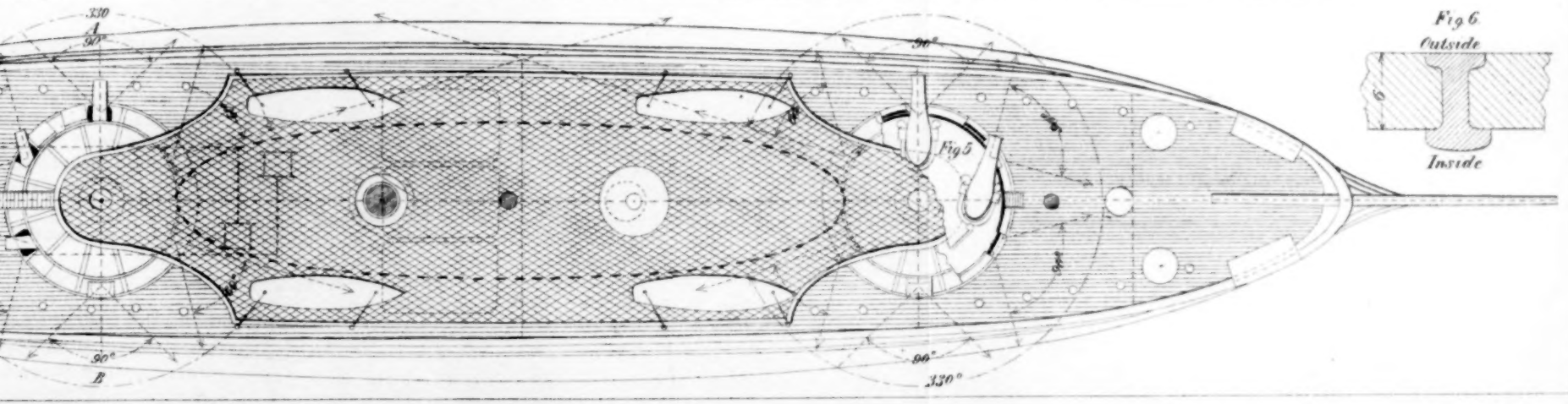


Fig 6

Iron-Built Armor-Plated Vessels.

From the London Artizan, Feb., 1863.

On the 19th ult., Mr. T. Barras read a very interesting paper in the theatre of the Royal United Service Institution, on the proposed plan for a wholly iron-made armor-plated vessel. Captain Fishbourne, R. N., occupied the chair. The view taken by Mr. Barras of the subject was of a three-fold character. He said such a ship as he proposed should be regarded hydrostatically, as a body designed to float; mechanically, as a beam subject to great pressure; and in the third place as a battery designed for purpose of attack and defence. A ship to be constructed on his principle should have a flat bottom amidships, where the boilers and coal bunkers were, and should be constructed wholly of iron, in three sheets of iron plates, riveted together in such a manner as to be protected either by an outer or inner coat of the plating. He strongly objected to a ship built of mixed materials differing widely from each other in chemical properties, as they never could work in harmony together. One point connected with the present construction of ships demanded consideration, and that was the destructive electrical action which took place in salt water with mixed constructions of iron and wood, with fastenings of brass. It was this electrical action that caused the high ratio of illness occurring in the finest armor-plated ships, and the curious results elicited by *La Goire*. As for the present system of shipbuilding, the probable results might be anticipated—the most serious and ruinous expenses would be gone to on ships that could not be expected to last for a dozen years; while a ship constructed as he proposed, he ventured to affirm would be an efficient ship for half a century, if not longer. Mr. Barras entered into particulars, tending to show that the vessel thus put together would answer all purposes for which she would be required.

For the Journal of the Franklin Institute.

On the Economy Resulting from the Expansion of Steam.

By W. Barnet Le Van.

A great deal has been said lately in regard to expansion and full travel of steam, and reference has been made to Hecker Brothers' "Metropolitan" flour-mill, where engines with cut-offs were tried with less economy, they assert, than when the same used steam during full travel of piston, which are now in operation at their mill.

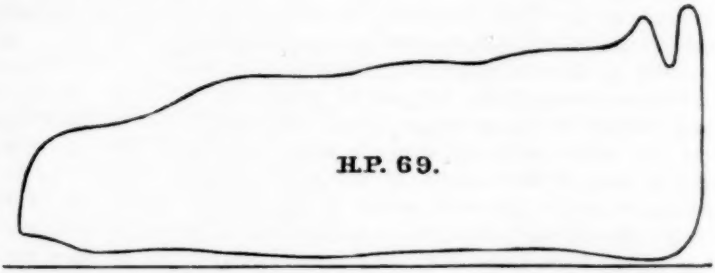
It is stated in public print that with the present arrangement they can make one barrel of flour by the use of 50 pounds of coal, and this is considered one of the good results of full travel.

The following diagrams were taken from different sets of engines which operated under nearly the same circumstances; if any difference the full travel engines had the advantage, as shown below.

Card Fig. 1 was taken from the full travel engines, diagrams from each engine being alike after having been put in good running order by one of the best shops in this city; the party being in no way concerned in taking the diagrams or replacing the engines. At the time

the diagrams were taken, the engines were running day and night continuously, and the experiments were prolonged to two weeks. The *best* result showed that 2000 pounds of coal made 45 barrels of flour; in other words, to manufacture one barrel of flour 44·45 pounds of coal were required.

Fig. 1.



Mill runs day and night for	6 days, or 144 hours.
Consumes	50 tons coal.
Duty	45 barrels per ton.
Engines	2
Boilers	4 (tubular).
Horse-power	69 each.
Revolutions per minute	55
Pressure of steam in boilers in lbs.	100
Scale of indicator	40 lbs. to an inch.
Diameter and length of stroke	16 by 30.

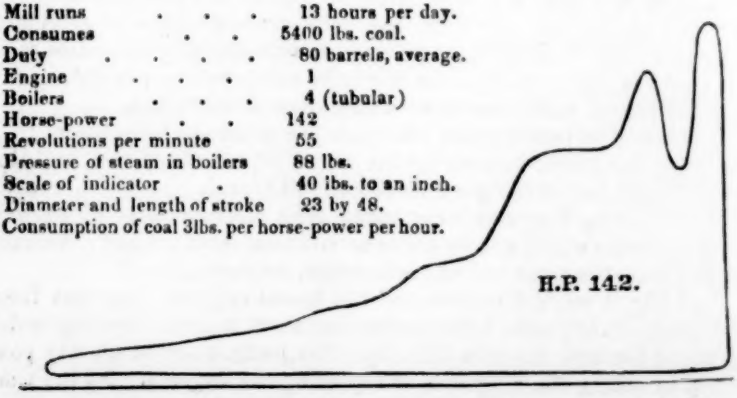
Consumption of coal, 5½ lbs. per horse-power per hour.

Card Fig. 2 was taken from an engine supplied with an *adjustable cut-off* and put in place of the *full travel* engines mentioned above—boilers, machinery and duration of trial the same. Instead of running day and night, the time of run was 13 hours; during the remaining 11 hours the fires were "banked" and engine and machinery allowed to stand. The average result, under these circumstances, was 80 barrels of flour to the ton of coal (2000 pounds), which is 25 pounds to the barrel.

Fig. 2.

Mill runs	13 hours per day.
Consumes	5400 lbs. coal.
Duty	80 barrels, average.
Engine	1
Boilers	4 (tubular)
Horse-power	142
Revolutions per minute	55
Pressure of steam in boilers	88 lbs.
Scale of indicator	40 lbs. to an inch.
Diameter and length of stroke	23 by 48.

Consumption of coal 3lbs. per horse-power per hour.



The builders of the adjustable cut-off engine guarantied 45 per

cent. more work, with the same amount of fuel, than the full travel engines. The result shows a saving of 80 per cent.

I present these facts for the consideration of those who are interested in the subject.

Philadelphia, Feb., 1863.

Ventilation of Iron-Cased Frigates.

From the London Artizan, Feb., 1863.

The plan of ventilation which is now being carried out on board the frigate *Royal Oak*, under the direction of Captain Fanshawe, who is the inventor of the system, differs in several respects from the method hitherto adopted for securing ventilation for our large line-of-battle and other ships. As applied to the *Royal Oak*, and other armor-plated vessels of the same class, it promises to be exceedingly effective. In securing a ventilation of the main deck, comparative little difficulty will be experienced; it is therefore in the lower deck that the method recommended by Captain Fanshawe will be more particularly adopted. The masts of the *Royal Oak*, being of iron, and all hollow, advantage is taken of this to make them air-shafts for carrying off the vitiated air from each deck. An aperture is accordingly made in each mast, which being opened and closed at pleasure, permits the foul air, of all the decks to be carried upwards. The different berths, stores, and compartments on the deck, instead of being closed up as in ordinary vessels, are supplied with gratings by which the foul air may escape. The essential point in Capt. Fanshawe's system is that there shall be a constant current of air circulating in every portion of the vessel, approximating as closely as possible to the upward and downward currents of a mine.

Translated for the Journal of the Franklin Institute.

Air-Bubble Thermometer, with two Indexes. Communicated to the Philomathic Society of Paris, by M. E. BARBIER, *Astronome-Adjoint* of the Paris Observatory.

I.—*Thermometer Indicating at the same time the Maximum and Minimum.*

1. *Idea of the Air-Bubble Thermometer.*—The minimum thermometer of Rutherford contains an enamel index which the alcohol draws with it as it contracts, but which it does not push forward in expanding. All its movements are retractions. M. Doulcet saw badly made indexes remain stationary when they ought to have retrograded; remarking that they fell to the liquid meniscus by the action of their weight, he got the idea of his maximum-thermometer.

If in an alcohol thermometer, the bulb upward, there be placed an index in the form of a blunt pin, so that this index will fall with its point foremost, the pin will stop at the meniscus of the alcohol, and will follow it if it move by an elevation of the temperature, but

will remain in its place if from the effect of cold the meniscus rises. This index, which thus by its point denotes a maximum, is of remarkable steadiness, the tube may be shaken smartly without altering its indication.

The Doulcet thermometer indicates the maxima as well as the minima, and gives its minima like a good Rutherford thermometer. But the reversed position of the instrument permits (especially at the moment when the meniscus is pierced by the point of the index) a portion of the liquid to trickle along the walls of the tube. This is the principal inconvenience of the Doulcet thermometer.

As an accident suggested it to him, so it was an accident which led me to devise the air-bubble thermometer.

A Doulcet thermometer which I was carrying from Nice to Cannes, fell twelve feet upon the turnpike road, which was at that season fortunately covered with a thick coat of dust. The cotton packing and sheet-iron case prevented the breaking of the glass, but not the rupture of the liquid column of the thermometer; five or six bubbles of air separated the alcohol into various parts, in one of which the index was contained. Having leisure, I endeavored to restore the continuity of the liquid column without the assistance of force or great heat.

I hoped that the movement of the liquid produced by the heat of the hand and that of the index as the tube was placed in different positions, would suffice. I soon succeeded in leaving in the tube but one bubble, upon which the head of the index rested, but this poor ram could not overcome this small bubble, and I conceived the idea of using the resistance of bubbles for the construction of a thermometer. Two indexes of a pin-form, having their heads turned towards a bubble, should be pushed, the one in one direction, the other in the other.

In the month of July last, I communicated this idea to the *Society of Science, Letters, and Arts* of Nice, presenting to them the Doulcet thermometer. My examinations having recalled me to Paris, I thought of realizing the idea which I had imagined. I had a second index placed in a Doulcet thermometer, and having developed a bubble of air so as to separate the two indexes, I had the satisfaction of seeing in the same horizontal tube an index which moved only forward, and another moving only backward; a maximum and a minimum index.

It seemed to me that the extreme temperatures given by the same instrument, left to itself, would be strictly comparable; and that, moreover, the leaking which took place in the Doulcet thermometer would be in great part avoided by the horizontal position of the tube. My experiments lead me to believe that this thermometer, easily carried and adjusted without assistance, except from the hands of the observer, will be found useful in meteorological observations. I did not hesitate to present to M. Leverrier a note, which he kindly read to the Academy of Sciences.

With a thermometer about fourteen inches long, and weighing with

its case about 3 oz., maximum and minimum determinations may be made to 0°·2 cent. (0°·36 Fahr.) M. Marié-Davy and M. Renou have been kind enough to begin the study of this thermometer.

2. *Method of Observation.*—The point indicated by the head of the minimum-index is first read, then that by the head of the maximum-index; the bulb of the thermometer is then warmed while it is in a vertical position, with its bulb down, in order that the maximum-index may be in the alcohol; when it is entirely immersed, the temperature of the bulb is lowered below the maximum which is next to be observed, and the instrument is suddenly inverted, the head of the two indexes approach each other and are now separated only by the air-bubble. The instrument placed horizontally is then ready to give a new maximum and minimum. The bubble of air resists all movements, provided there be no shock sufficient to cause new ones. If the instrument be deranged by a very violent jerk or a considerable blow, it is easily put in condition to give again its indications.

3. *Correction.*—Each index may be considered as indicating by its head the extremity of a thermometric column. The zeros of these imaginary thermometers will be at the points where the heads of the indexes would be when the bulb of the thermometer is buried in ice.

Double Tell-tale Thermometer.—Imagine at a certain point in a vertical thermometer tube whose bulb is downwards, a bubble of air transpierced by an index whose head is upwards; and outside of the liquid a second index sticking to the side of the tube with its head downwards. The thermometer thus arranged would show by the fall of one or both indexes, that the one or the other of the two corresponding temperatures had been passed, or that the temperature has not remained within the limits assigned by the placing of the two indexes. Such an instrument would be valuable in a hot-house, and particularly in a cocoonery, where it is important that an observable phenomenon, besides the death of the worms, should announce to the master that the overseer has been negligent. The use of a magnifying-glass renders the indexes easy of observation.

II.—*Movement of an Index in the Tube—Phenomena Observed.*

1. An index falls head foremost when the thermometer is suddenly reversed. This is the Rutherford index, and is easily displaced in the tube.

2. An index is easily introduced by its point, the thermometer, held horizontally and gradually inclined, being slowly turned in the hand; when the point is once engaged in the tube, the thermometer is suddenly and completely inverted; the index falls through the liquid column to the meniscus, which it follows in its movements, produced by a rise of temperature, but not at all in those produced by cold. This is a maximum Doulcet index; and when abandoned by the alcohol it is remarkably stable.

3. An air-bubble resists the penetration of the head of an index. It

can be only made to penetrate it by striking the tube on the palm of the hand, while the index is guided by the other, without holding it.

4. An index coming in contact with an air-bubble by its point, penetrates it either by change of temperature or by a blow on the palm of the hand.

5. An index of which one portion is out of the liquid, cannot be moved except by a shock.

6. If a change of temperature brings a drop of alcohol into contact with the point of an index which is entirely or partially out of the liquid, the bubble will, if it be close above the index, trickle along it from the point to the head, and if the tube be shaken will run down along the walls.

7. When the indexes touch each other, head to head, and the instrument being held bulb upwards, the meniscus of alcohol is brought by cooling, to the point of contact of the indexes, a strangulation of the column takes place by which a small bubble of air is introduced, which mounts along the upper index. These bubbles form regularly and unite above into one, which soon acquires proper dimensions. The thermometer is then warmed to give the separated portion of the liquid a sufficient length; and by subsequently cooling with the bulb down, the lower index is lodged in the separated column, and by the cooling moves from the upper. You have then a minimum vertical thermometer; if the instrument be heated, you have the tell-tale, &c.

By this mechanical method of producing the air-bubble, these thermometers can be rapidly made without requiring any peculiar skill in the operator.—*L'Institut.*

Gunpowder made of Paper.

From the Lond. Mechanics' Magazine, December, 1862.

We read in a Copenhagen letter:—The Royal Artillery, some days ago, made experiments with gunpowder made of paper, which turned out a success. Common packing paper was, in the course of 10 or 15 minutes, transformed into a very powerful kind of gunpowder, and a number of different shots were fired with it. The invention, which seems to be very interesting, belongs to a foreigner.

For the Journal of the Franklin Institute.

Locks and Safes. Discussion in the Polytechnic Association, New York, Friday Evening, Jan. 16, 1863. Communicated by J. D. STETSON, Secretary.

S. D. Tillman, Esq., in the Chair.

J. P. Frazer, of New York City, exhibited and explained his Door-fastener. It is intended to be used by travelers as an additional security to the door, and consists of two pieces of metal and a screw. One of the pieces hooks into the cavity where the spring-bolt stands, and the other piece is inserted through a mortise, and stands across so as to take hold of the door and door-frame. The screw tightens the connexion and makes a perfectly firm job. The piece that extends across is so formed, that, by turning it over, the device may

be adapted to rim-locks or mortise-locks, as may be required, and the screw is of sufficient length to compensate for all irregularities and inequalities in the thickness of the work. Several members commented on it, and expressed favorable opinions of its merits.

Mr. Stetson, in alluding to the faults of ordinary locks, their liability to be turned by forceps if the key is left in the door, and their liability to be picked by simple instruments from the outside, (this requiring very little skill) if the key is withdrawn, explained how the difficulty might be partially obviated, either with or without a device like this of Mr. Frazer. The plan—not original with him—was to withdraw the key partially from the door, and to place a wash-bowl or pitcher under it in such a manner that any interference with the lock would probably detach the key and cause an alarm by its fall.

Mr. Bull introduced Mr. Hobbs, of London Crystal Palace celebrity, who was listened to with great interest.

Mr. Hobbs explained the general nature of Locks. They were all capable of division into three great classes, or in fact two, one of the two being again subdivided. The first class was the ward lock, in which the security depended on the introduction of a greater or less number of impediments skilfully distributed so that an elaborately shaped key was required to pass them and move the bolt. These were easily opened after the very simple operation of taking an impression of the wards by wax or a smoked key. The second general class was the tumbler lock, in which the security depended on the employment of movable obstacles, which all required to be removed, and which could not be thus avoided. The single tumblers originally provided were levers which might be avoided by elevating them, either just sufficiently or to any extent more than sufficient. These were soon replaced by the double tumbler, in which a notch was introduced in the lever, and a lifting of the lever or tumbler too much, would be as ineffective as not lifting it at all. These locks were, however, readily picked by a gradual feeling of the right position of each tumbler, which right position, when gained, was easily detected by a skilful operator. Mr. Hobbs explained here the great refinement to which this branch of the art had been carried. He declared it impossible to file or otherwise produce a series of tumblers of so uniform a size or length that all, even if mounted with the greatest delicacy on the same cylindrical pin, would be equally pressed upon by the stump, or the projection on the bolt, which struck them. If all *were* equally pressed, the removal of one or the removal of its resistance to the bolt by turning it until its notch matched the stump, would release the bolt so that the latter would move sensibly back, it being understood that a constant and tolerably severe strain was kept up on the bolt during this operation. In other words, the elasticity of metal is such, that in a lock of ten tumblers, if all bore equally to resist the strain applied by a burglar on the bolt, the bolt would move back until it met and pressed firmly against these several tumblers and there stop. If now the burglar, by turn-

ing one tumbler gradually around, puts it in such position that the notch matches the stump, so as to relieve that tumbler from its share of the strain, the whole strain being thrown upon the other nine, would compress those nine further than before, and the bolt would move. The extent of this motion would be, of course, very slight, but it was appreciable and actually measureable; he had a micrometer which multiplied the extent of each motion 20,000 times; a variation in the position of the bolt equal to a thickness of tissue paper, would be indicated by his instrument to the thickness of twenty reams of such paper.

The skill of lockmakers had always kept in advance of the skill of burglars, and he believed it always would. The manufacture of locks was progressing very rapidly. It had made progress within the past year. Before the burglars had really learned this mode just described, of picking, lockmakers introduced what were known as false notches, notches of one-eighth inch depth, or sufficient to relieve entirely the strain on the tumblers, and to cause the lock to behave in all respects as if that tumbler had been placed in its proper position, and yet when all the rest had been really properly placed, the bolt could not be withdrawn, but would only move to the small extent allowed by the false notch, and would then be stopped as effectually as before. But this, in turn, could be readily surmounted by skill and patience. It mainly required the latter alone to adjust successively all the tumblers of the most elaborate locks, no matter what number of false notches were employed.

The second division of the tumbler locks, a branch of the lock family which might perhaps be designated with some propriety as an entirely independent one, though resting in fact upon the same tumbler principle before explained, was the dial lock or letter lock, called by the latter name in consequence of its being customary to designate the position of the dials or indices employed by the letters of the alphabet. These had no key. That was the distinguishing feature of this kind of lock. Some of the most recent varieties of the other division, it should have been remarked, were made without keyholes, or rather locks were so made in some instances that the keyhole was closed while the lock was being operated. In such locks the key was introduced and turned round and caused to fulfil its functions, while all access to the interior of the lock was closed by a plate or strong covering. But the dial lock had neither key nor keyhole. It depended on the placing of the tumblers in right positions by the turning of parts on the outside, either the same part being turned successively in various positions, and thereby adjusting the interior parts, or by the adjustment of several dials or rings, separately exposed on the exterior. Some of these locks were very easily picked or opened, but others, both of this class and of the other, the double tumbler lock with keys, Mr. Hobbs thought, were, in the present state of the art, unpickable. He believed that the art was advancing, that every lock now known would ultimately—probably very soon—be overcome by the skill, not, he hoped, of actual burglars, but of those amateurs,

or rather of those students who, in the interest of the community, studied to perfect the constructions, by discovering and remedying their weaknesses.

All locksmiths, even those engaged in the manufacture of the most ordinary locks, understood, if they did not practice, picking by pressure. But the cheap locks were generally sufficient for ordinary purposes. A perfectly impregnable lock was not needed on a street door, or on any other door where a jackknife could remove a panel, and, as a general thing, the cheap locks were as perfect in their line, and perhaps advancing as rapidly towards still higher perfection, as the more costly structures. The Secretary had explained his mode of securing his door in hotels. He (Mr. H.) would explain his, which consisted in turning a chair upside down and resting it delicately against the door so that any movement would throw it down.

His (Mr. Hobbs') success in England had been adverted to by others. He had found the condition of affairs in England with regard to the protection of property, very different from that here. They relied more upon watchmen there. Their watchmen were not ignorant and careless laborers, but well trained men who had served for generations in the same business and knew nothing else but banks and the safety of bank property. They were born in banks and died in banks. He carried the Day & Newell lock to England, and when he had been successful in picking the famous Chubb lock in the Great Exhibition, gave the Chubb parties an opportunity to recover their money, by offering the same premium to any who would pick his Day & Newell construction. It had been tried by several parties, each using up the thirty days allowed without success. But it would be hardly safe now to make such an offer to him (Mr. Hobbs). He had sold but few of those locks in England. He was sent for to the Bank of England, and believed that he was going to accomplish something great at that place, but found that the price named, fifty guineas, was esteemed perfectly frightful. He was told that it would never do to name such a price to the Directors. Mr. Hobbs told the gentleman that he could furnish a very good lock for twenty guineas—it would be the same one, by the way! He was exposing no trick of the trade in confessing that which was already well known, not only in the sale of locks, but in many other branches of business. He sold the Bank of England a lock, and supposed it would pave the way to a very extensive introduction, but it did not. In America, every bank in the country which had a capital of $100,000 justly estimated $250 a small consideration for a suitable lock, but in England twenty and thirty guineas was the highest practicable price.

Picking the Bramah lock he esteemed his greatest performance. This lock hung in a window in Picadilly with a challenge of 200 guineas appended in large letters, and he had been weak enough to make a small bet before leaving America, that he would bring home the guineas, or at all events would open the lock. He succeeded in doing both. But the difficulties were far greater than with the famous 16-tumbler Chubb lock in the Exhibition. Bramah's had 18 tumblers or

equivalent slides, all radiating from a centre. The key was a conical stem with delicate grooves on its exterior, and slid into a key-hole which was only a quarter of an inch in diameter. This latter was the whole space through which to introduce instruments. Considerable effort was required to bring the parties actually to the sticking point. The challenge was a specious one; it read as follows: "The artist who produces an instrument which will pick this lock, shall receive 200 guineas the moment the same is produced." It looked bold, but really meant very nearly nothing at all. When the trial was finally agreed on, the lock was bolted on a mass of wood and he was allowed to go to work. A spring, usually but slight, was used to resist the entrance of the key, but in this lock that spring required a force of fourteen pounds to urge it back. The key-hole, though small, allowed a screw to be put in which forced back the spring and held it. After nearly eighty hours' measuring and preparation, Mr. Hobbs succeeded in opening the lock, and then successively locked and opened it three times in an hour in the presence of the umpires agreed on. The triumph came near being fruitless, however, in consequence of an unexpected and apparently very slight circumstance. It was conditioned that the lock should be readily opened by the proper key—the old key—when the operation was completed. This was to test the success of the operation in not destroying or injuring any of the works. When Mr. Hobbs' work was finished and his tools removed, one of the umpires, a very good mechanic, took the key and advanced to the lock to open it, Mr. Hobbs and the other gentlemen, of course, standing back. He applied the key and attempted to turn it without effect. Mr. Hobbs wished to show him how, but was forbidden, and for a moment the prospect looked blank. The umpires, however, decided that he should be allowed to make, standing in his place and in the hearing of all parties, such directions as he saw fit, and they would then decide whether the instructions were legitimate or not. He told him to press in the key further, because the resisting spring was unusually stiff. With this explanation the lock was immediately opened.

The arbiters were called away to Paris on another matter, and the payment was then declined by the Bramah parties on the ground that the challenge attached to the lock in the window was the only one ever formally made by them, and no single "instrument" "produced" by any "artist" had opened the lock. On the return of the umpires they pronounced this excuse frivolous, and the gold was paid. Mr. Hobbs said that he had, perhaps rather weakly, allowed the gold to be exhibited with a descriptive label in the Exhibition, and the only slash he had received from any of the London journals, which hit him hard, was one from the *News* the next morning, in which it was remarked that the triumph would have been complete except for the fact that the victor, in true Barnum style, had exhibited the gold.

Mr. Hobbs told an amusing story of opening a very elaborate French lock, on the letter or dial principle, and changing the combination while the exhibitor's attention was diverted by his friend, and then asking the exhibitor how it worked; first compelling him to a very

petulant exhibition of slight irritable qualities, and finally to an elaborate rehearsal of all the expletives in both the French and English languages, when he found that he could not open his lock himself, while Mr. Hobbs could. The exhibitor subsequently watched his lock very carefully. Mr. Hobbs said that was the best way to make many of the "ingenious" locks secure.

The warded lock was of Roman origin. The movable tumblers were of Egyptian origin. The letter lock, or dial lock without key, was first introduced, Mr. Hobbs thought, by Regnier of Paris, about 1762.

Mr. William H. Butler, of the firm of Valentine & Butler, being called upon, said that powder had done away with the open key-hole, and had introduced a great change in locks during the last two years. He thought blowing up locks and safes with powder, was more practised in this country than in England, perhaps in consequence of the absence of as efficient watchmen here. Even five and ten dollar locks must be made powder-proof now, or they would not sell in this country. One of the great advantages of the dial lock lay in the fact that no possible space existed for the introduction of powder. He believed that, ten years hence, no safe with a key-hole would be tolerated where any inducement existed for burglars.

Dr. Rich asked if gunpowder always or generally *opened the safe*, and whether it might not frequently, by deranging and bending the parts, make the bolt more immovable than before.

Mr. Butler said it generally opened the works so effectually that the contents of the safe were very easily made available. A very common way, and one which unfortunately would seem to be as effective against the dial lock as any other, was to drill a hole through the exterior, either of the lock or of some adjacent portion of the door, and deposit the powder in the cavity thus made accessible. Pieces of the doors of safes had been thrown in some instances upon the tops of adjacent buildings.

Mr. Stetson asked if, under such circumstances, the burglars usually obtained possession of the valuable contents of the safe before the alarm brought others to the spot.

Mr. Butler said the noise was very greatly deadened by stopping the windows and outlets of the building, and covering the safe with bagging and like deadening material. The robber usually remained concealed until he found no alarm was raised, and then quietly removed the money and withdrew.

The subject of cheap locks was introduced, and the lock of Mr. McWilliams again exhibited. Mr. Hobbs agreed with Mr. Butler that this was a very ordinary lock and very easily picked, but like many others of less pretensions, was a good cheap lock. The street door lock of Valentine & Butler was alluded to by several members as one which was operated by a very small key. The key is a thin plate of metal properly notched at the end, and is incapable of turning, but produces its effect by direct pressure against the tumblers. Mr. Butler thought several tons of metal were toted about the city at the present moment needlessly, in the form of heavy keys in the pockets of

our citizens. Mr. Hobbs did not believe that this or any lock with three or four tumblers with false notches, *would* be picked by burglars on a street door.

Allusion was made by Mr. McWilliams, Dr. Rowell, and others, to a lock which was operated differently on the inside from the outside by the same key, and which was highly useful on the rooms of hotels. The guest, on leaving his room and locking the door from the outside, left it in such a condition as to be very easily opened by the chambermaid, but on retiring and locking it on the inside, no skill yet known, even of the most accomplished burglar, could open it from the outside.

PROCEEDINGS OF THE BRITISH ASSOCIATION.

From the London Athenæum, Oct. 1862.

Section G.—Mechanical Science.

The Secretary read a paper by Mr. C. Atherton, late Engineer of the Royal Dockyard, Woolwich, "On Unsinkable Ships." The author pointed out the importance of having ships made of a material of less specific gravity than water; so that, whatever injury the ship may sustain so as to admit water, they would never sink, and thus both crew and ammunition or treasure might be saved. He considered such a build would be very valuable for small vessels, which could enter where the large armor-plated ships would be stopped. The idea, he thought, was worthy of consideration.

Dr. Fairbairn, the President of the Section, read a paper "On the Results of Some Experiments on the Mechanical Properties of Projectiles." He commenced by stating that, in the investigations which had taken place with regard to projectiles and armor plated ships, one great difficulty that had arisen was to get good plates of sufficient thickness, and vessels of sufficient tonnage to carry those plates. It appeared that they were limited to plates of 5 ins. in thickness; with plates heavier than that, a ship would not be what was technically called "lively." He had attended the experiments at Shoeburyness from the commencement, and they had reference to the force of impact. He would state the results of the more recent experiments, which had not yet been published. The first series of experiments had reference to the quality of the plates and the properties of the iron best calculated to resist impact. There were three qualities required: first, that the iron should not be crystalline; but secondly, that it should be of great tenacity and ductility; and thirdly, that it should be very fibrous. The mean statical resistance to crushing of the two flat-ended specimens of cast iron is 55·32 tons per square inch. The mean resistance of the two round-ended specimens is 26·87 tons per square inch. The ratio of resistance, therefore, of short columns of cast iron with two flat ends to that of columns with one flat and one round end is as 55 32 to 26·87, or as 2·05 to 1—an extremely close confirmation of Prof. Hodgkinson's law. Applying this same rule to

the steel specimens, it would appear that the flat-ended shot should have sustained a pressure of 180 tons per square inch before fracture. In the experiment it actually sustained 120 tons per square inch without injury, excepting a small permanent set. In the experiments with cast iron, the mean compression per unit of length of the flat-ended specimens was ·0665, and of the round-ended ·1305. The ratio of the compression of the round-ended to the flat-ended shot was, therefore, as 1·96 : 1, or nearly in the inversed ratio of the statical crushing pressures. Applying this law to the case of the steel flat-ended specimen, it may be concluded that the compression before fracture would have been only ·058 per unit of length. The determination of the statical crushing pressure of the flat-ended steel shot as 180 tons per square inch and its compression as ·058 is important, on account of the extensive employment of shot of this material, size, and form in the experiments at Shoeburyness. In the case of the lead specimens, the compression with equal weights was the same whether the specimen were at first round-ended or flat-ended. This is accounted for by the extreme ductility of the metal and the great amount of compression sustained. In regard to the wrought iron specimens, it may be observed that no definite result is arrived at, except the enormous statical pressure they sustain, equivalent to 78 tons per square inch of sectional area, and the large permanent set they then exhibit :—

	Statical Resistance in Tons per Square Inch.	Dynamical Resistance in Foot lb. per Square Inch.
Cast iron, flat-ended,	55·32	776·8
Cast iron, round-ended,	26·87	821·9
Steel, round-ended,	90·46	2515·0

In the experiments on the wrought iron specimens, the flat-ended steel specimens, and the lead specimens, no definite termination was arrived at, the material being more or less compressed without any fracture ensuing. The mean resistance of the specimens of cast iron is 800 foot pound per square inch; that of the specimen of steel is 2515, or rather more than three times as much. The conditions which would appear to be desirable in projectiles, in order that the greatest amount of work may be expended on the armor-plate, are—1. Very high statical resistance to rupture by compression. In this respect, wrought iron and steel are both superior to cast iron; in fact, the statical resistance of steel is more than three times, and that of wrought iron more than two and a half times that of cast iron. Lead is inferior to all the other materials experimented on. 2. Resistance to change of form under great pressure. In this respect hardened steel is superior to wrought iron. Cast iron is inferior to both. The shot which would effect the greatest damage to a plate would be one of adamant, incapable of change of form. Such a shot would yield up the whole of its *vis viva* to the plate struck; and, so far as experiment yet proves, those projectiles which approach nearest to this condition are the most effective. The President stated that steel shots might be made at a comparatively small cost. M. Bessemer had told him, that

if he had a large order he could produce steel shots at a little more than the price of iron; but if the ingots as cast had to be rolled or hammered to give them fibre, they would cost near £30 a ton, instead of £8 or £10 per ton.

Mr. J. Nasmyth inquired whether chilled cast iron flat-headed shot had been tried? The process of chilling cast iron was very simple and inexpensive. If chilled flat-ended cast iron shot had not been tried, it was very desirable it should be.—Dr. Fairbairn said they had not been tried; but he believed that shot thus made being hardened to a certain depth, having its velocity the same, would in striking the object break as if it had not been hardened at all. However, he would have experiments made; and he hoped that before the next meeting of the Association the matter would be proved experimentally.

Mr. T. Aston read a paper "On Projectiles with regard to their Power of Penetration." After alluding to the interest with which the contest between artillery and armor-plates has been watched by the country, he explained what was the actual condition of this important question so late as May last, by quoting statements which had been made in Parliament and elsewhere, that after all the vast expenditure upon our new artillery, the navy of England is compelled to arm herself with the old smooth-bore; and that is the best gun the navy actually possesses, though admitted to be so inefficient. Such being the state of the question a few months ago, Mr. Aston proceeded to consider, first, the reason why the artillery hitherto employed in the service (including rifled guns and smooth-bores) has always failed to make any impression on the plated defences at ordinary fighting range; and, secondly, by what means artillery science has lately reconquered its lost ground. Three conditions were laid down as necessary to enable artillery to attack successfully armor-plate defences:—1st, the projectile must be of the proper form; 2d, of the proper material; and, 3d, be propelled from a gun able to give it the necessary velocity. The artillery of the Ordnance Committee failed because they utterly neglected the first two conditions, and had recourse to the brute force of the smooth-bore for the third. The expression accepted as representing the penetrating power of shot was "velocity squared multiplied by weight;" but the form of the shot and the material were conditions altogether omitted from the expression; and the importance of the omission will be obvious at once if an analogous case—say a punching machine employed to perforate wrought iron plates—be taken. What would be the result if the punch which is made of suitable shape and material were removed, and a round-headed poker of brittle cast iron or soft wrought iron were substituted in its place? The great importance of velocity was conceded at once—it is a *sine qua non* condition; but there has been great misconception in supposing that the old smooth-bore gives a greater initial velocity than the rifled gun, as the results obtained would show. The average initial velocity of the 68-pounder is, in round numbers, 1600 feet per second, with a charge of powder one-third the weight of the shot, the length of the shot being, of course, one calibre. Sir W. Armstrong stated, that with a charge

of powder one-quarter the weight of the shot, he obtained with his rifled gun an initial velocity of 1740 feet per second. He did not state the length of his projectile. Mr. Whitworth, with a projectile two calibres long, obtains an initial velocity of 1900 feet per second; and with a projectile one calibre long, like that of the smooth-bore, an initial velocity of 2300 feet per second; being greater than that of the smooth bore in the proportion of 23 to 16. The following table shows the actual results obtained by various guns:—

Gun.	Range.	Projectile.	Powder Charge.	Penetration into Armor-Plate.
Armstrong 110-pounder,	200	110 lb. solid.	14 lb.	1½ to 2 inches.
68-pounder smooth-bore,	200	68 lb. solid.	16 lb.	2½ to 3 inches.
Whitworth 70-pounder,	200	70-lb. shot and shell.	12 lb.	Through plate and backing.
Whitworth 120-pounder,	600	130-lb. shell.	25 lb.	Through plate and backing.

The first two results show that the Armstrong rifled gun is a worse compromise than the old gun it was intended to supersede. It is worthy of notice, that the velocity of the Whitworth heavy projectile, after traversing 600 yards (a good fighting range), was 1260 feet; being 50 feet greater than the initial velocity of the Armstrong projectile, which is 1210 feet at the muzzle of the gun. The total results in respect of penetration being so decidedly in favor of Whitworth, it follows that he has adopted the best compromise, by combining all three necessary conditions of proper form and material of projectile and sufficient velocity. That the velocity, though perhaps at the muzzle of the gun slightly below that of the smooth-bore, is sufficient when combined with proper form and material of projectile, is shown by the penetration result, which in the case of the Whitworth is through and through both armor-plate and backing; in the case of the smooth-bore is barely through half the armor-plate; and in the Armstrong is not half through. The form of projectiles, both shot and shell, employed by Mr. Whitworth for penetrating armor-plates, was then described. The material of which the projectile is composed is what is termed homogeneous iron—combining the toughness of copper with the hardness of steel. It undergoes a carefully regulated process of annealing. The same metal is used for the Whitworth field guns; and practical improvements now enable it to be worked in masses of any requisite size, whose quality may be henceforth depended upon with certainty. Mr. Whitworth is therefore now making his heavy ordnance with both interior tubes and outer hoops of homogeneous metal of the improved manufacture; so that the guns will be constructed throughout of one uniform metal, without any welding at all. Experience justifies the

expectation that they will be free from the objections which it is well known are inherent in all welded guns, and be fully able to resist the severe and searching strain that is sure sooner or later to disable a gun built up of forged coiled tubes, if it be called upon to do its full work by discharging heavy projectiles at efficient velocities.

Mr. Nasmyth said the steam-ram was an old subject with him. A plan was proposed by him to the Admiralty so long ago as 1845. He thought the more destructive you can make the attack on your adversary the better. It was not right to be torturing your enemy by drilling numerous small holes in him: it was like taking a whole day to draw a tooth. His idea was to make one large hole and sink the ship at once with the enemy. It was a question of momentum. The first practical ram was the *Merrimac*; but the Southerners made a mistake in giving her a sharp end: it should be blunt; and such was the original plan of the author, nor had he seen any reason to alter his views. The vessel must present as low an angle as possible to turn shot; but she must also have strength in the direction of her length, and use the utmost possible amount of steam to get velocity; and, to meet the objection that the impact might destroy the engines, which he did not anticipate, he would place the engines on a slide, with buffer arrangements. With such a vessel he would dash into the *Warrior* as into a bandbox. The plates would be crushed at once. He hoped the Admiralty would devote a thousand pounds or two to try the effect of a ram against some old hulk, then the *Trusty* with armor-plates, and afterwards against the *Warrior* herself; and he thought it would be best to knock a hole in her ourselves, in preference to having it done by an enemy.—Mr. Webster hoped that in the discussion they would not omit the question, brought before the Section by Mr. Atherton, of unsinkable ships. It was quite clear from the late experiments that ships could not withstand the attack of guns, and there was a reason why we should give some attention to other matters of ship architecture than the mere attempting to defend them by armor-plates against shot.—Admiral Sir E. Belcher observed that in 1818 he had urged a plan of unsinkable ships to Sir Robert Seppings by shutting down the hatches and using the pumps to pump in air: but this was objected to, on the ground that it was necessary to have an opening to keep the timber sound. He advised water-tanks as a backing to the sides of ships, believing that such an arrangement would withstand even Mr. Nasmyth's ram.—Mr. R. W. Woollcombe explained the nature of his projectile, by means of which he got rid of the friction caused by rifling, with no more windage, the projectile being a disk traveling in a direction perpendicular to its axis of rotation.—Mr. G. P. Bidder, Jr., observed that with a smooth-bore the balls go accurately for a short distance, but afterwards they diverge in uncertain directions; and this he showed must be the case as well with Mr. Woollcombe's shot as with an ordinary smooth-bore shot.—Captain Blakeley said that Mr. Aston had told them that Mr. Whitworth was beginning to use homogeneous metal for the inside and the outside of his guns; and he (Capt. Blakeley) would encourage him to use this, as he had for several years past

used it with great advantage. He had made guns, in use abroad, of large size, which would throw rifle 600-pound shot with 80 pounds of powder. The Spaniards had such guns; and he thought the English Government ought to give some encouragement for trials of every kind of gun as well as rams.—Mr. J. Scott Russell said at the last meeting it was ascertained that 4½-inch plates and 18-inch of wood would beat the gun: but the late experiments had shown that we have no navy if you keep wooden ships with iron plates. Sir W. Armstrong fired our wooden ships, and Mr. Whitworth had proved that he can do the same if the ship be plated. No ship of ordinary size was big enough to carry indestructible plates. Why could not a good fighting ship be made which should keep out a shell? He believed that Whitworth's shell would be stopped by double armor-plates, one in front and the other behind it; but a larger one, it was said, would be made which would destroy any thickness of double plates; and he believed it would be done. There was one way of carrying increased thickness, namely, by the increased size of vessel. There was, however, another way without increasing the size—to build the ship up but little beyond the water's edge; cover her below the water-line as far as was necessary to prevent penetration; then diminish the battery on the deck; and then they would have a vessel somewhat like the *Mon tor*, absolutely shot-proof. Capt. Coles' ship was, he believed, on that principle.—Dr. Robinson had lived long enough to learn that such prefixes as "im" and "un" were very unsafe syllables to deal with, whether as applied to unsinkable ships or the impossibility of making shot-proof ships. He thought, however, that the materials for unsinkable ships would have no power of resistance. He wished to know as to the price of a gun of the homogeneous metal as compared with one on the Armstrong principle.—Mr. Aston said that the price of homogeneous metal was gradually being lowered, and that the Whitworth gun could be produced at a lower price than the Armstrong.—Dr. Robinson, in continuation, observed that such was the arrangement of the Whitworth gun, that the friction in the barrel was reduced to a minimum. The shot would fall from the barrel with a very small inclination. He thought that Mr. Woollcombe's shot promised advantages in some respects, but he pointed out great disadvantages.—Mr. Aston asked what would be the condition of Mr. Scott Russell's ship with shells which would penetrate 30 feet below the water-line? and this, Dr. Robinson had told them, was possible. As to the partially defended ship, would any captain ask his men, some to stay in the undefended part, while others were comfortably ensconced behind 8 inches of armor-plate? He (Mr Aston) considered that guns built of rings could never stand.—The President said the great difficulty about homogeneous iron was its liability to be of unequal quality. Mr. Whitworth took very great pains in the manufacture, and the great danger in the case of the coils is that they are apt to elongate.

A short discussion then took place on Mr. Thorold's paper "On the Failure of the Sluice in the Fens, and the Means of Securing such Sluices against a similar Contingency."

(To be Continued.)

FRANKLIN INSTITUTE.

Proceedings of the Stated Monthly Meeting, Feb. 19, 1863.

John C. Cresson, President, in the Chair.

John Agnew, Vice President.

Isaac B. Garrigues, Recording Secretary.

The minutes of the last meeting were read and approved.

Donations to the Library were received from the Royal Astronomical Society, the Royal Society, the Institute of Actuaries, the Statistical Society, and the Society of Arts, London; Major L. A. Huguet-Latour, the Natural History Society, Montreal, and the Canadian Institute, Toronto, Canada; Capt. Wm. H. Swift, Boston, Mass.; B. H. Latrobe, Esq., and the Maryland Institute, Baltimore, Md.; A. D. Bache, LL.D., and Frederick Emmerick, Esq., Washington, D. C.; the American Philosophical Society, Charles J. Gobrecht, Esq., Isaac S. Cassin, Esq., Professor John F. Frazer, and Professor John C. Cresson, Philadelphia.

Donation to the Cabinet from the heirs of Frederick Haas, late of Germantown, Penna., through Joseph Haas, Esq.—a Stocking Machine imported by the early settlers of Germantown; now in complete working order.

The Periodicals received in exchange for the Journal of the Institute were laid on the table.

The Treasurer's statement of the receipts and payments for the month of January was read.

The Board of Managers and Standing Committees reported their minutes.

The Board of Managers reported that they have organized for the present year by electing Mr. William Harris, Chairman, and Messrs. Isaac S. Williams and Wm. A. Drown, Curators; and appointing the following Standing Committees:—

On Publications.	*On Instruction.*	*Managers of Sinking Fund and Finance.*
John C Cresson,	John F. Frazer,	Frederick Fraley,
B. H. Bartol,	Frederick Fraley,	Samuel V. Merrick,
Fairman Rogers,	Isaac B. Garrigues,	Evans Rogers,
Washington Jones,	Alan Wood,	John F. Frazer,
Robert Briggs.	George Erety.	George Erety,
		Jacob Naylor.

The Standing Committees for the ensuing year were appointed by the President, and approved, as follows:—

On the Library.	*On Cabinet of Models.*	*On Exhibitions.*
Henry Ames,	James Agnew,	John E Addicks,
James H Cresson,	Wm. B. Bement,	John Agnew,
George M. Conarroe,	James Fraiser,	James H. Bryson,
George Erety,	Mordecai W. Haines,	James H. Cresson,
John Ferguson,	John Horton,	William A Drown,
Henry D. Gregory,	John Kile,	Edwin Greble,
Raper Hoskins,	Wm. B. Le Van,	John Gardiner, Jr.,
Jas. T. Lukens,	Thos. H McCollin,	William Harris,
H. G. Leisenring,	John L. Perkins,	Jacob Naylor,
G. L. Martindale.	Coleman Sellers.	Thos. S. Stewart.

On Cabinet of Arts and Manufactures.	*On Cabinet of Minerals and Geological Specimens.*	*On Meetings.*
Jas. C Booth,	Robert Bridges,	Thos. M. Adams,
Thos. Bickerton,	Isaac H. Conrad,	Wm. H. Brown,
Henry Bower,	John F. Frazer,	George Burnham,
Chas. G. Crane,	Emile Geyelin,	Chas. S. Close.
David M Hogan,	Isaac B. Garrigues,	James Dougherty,
Joseph Klapp,	Henry Hartshorne,	Henry Howson,
C. Eugene Meyer,	B. Howard Rand,	Washington Jones,
S. G. Rosengarten,	Robert E. Rogers,	Edward Longstreth,
Eliashib Tracy,	Richard A. Tilghman,	Percival Roberts,
Wm. Weightman.	John C. Trautwine.	M. P. Simons.

On Meteorology.

Charles T. Adams,	James A. Meigs,
Charles M. Cresson,	Benjamin V. Marsh,
Thos. M. Drysdale,	Fairman Rogers,
John F. Frazer,	James S. Whitney,
James A. Kirkpatrick,	Thos. J. Weygandt.

E. G. Chormann's Improved Stereoscopic Instrument was exhibited. It consists of an outer and an inner casing, and a frame; the inner casing sliding within the outer one. To the front edge of the frame, which slides into the inner casing, is hinged two arms, each of which is provided with a ring for holding a lens. When the instrument is to be used, the frame is drawn from the inner casing as far as possible, without entirely removing it therefrom, and the arms turned out so as to be at right angles to the frame. The picture being secured to the outer case by a flat spring, which holds it against the same. The glasses may be applied to the eye as in the ordinary Stereoscope, and the adjustment made by sliding the inner case back and forth within the outer one, until the proper focus is obtained. When not required for use, the arms holding the lenses may be folded together within the frame, and the latter pushed into the casing; the whole being thus condensed into a compact form of such dimensions as to be contained within the vest-pocket without inconvenience to the wearer.

Mr. Thomas Shaw exhibited a specimen of Fractured Glass Tube, the peculiarity of which consists in the line of fracture, which is in the strongest direction, and instantaneous throughout the whole length (from 10 to 15 feet), without any apparent cause. This does not occur with tubes made in shorter lengths, other conditions being the same. He attributes the cause to the mode of straightening the tube, which is done in this wise. After the tube is drawn out sufficiently, it is held suspended in the air, and revolved until sufficiently cool to permit no further bending. It will be observed that this continual bending, which the above operation causes, must necessarily bring the glass to a state of *torsion* in the direction of the fracture. He has since had tubes made of the same length, in the usual manner, with the exception of cooling and straightening them upon a flat surface, that are free from this evil.